ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

AN ACTION RESEARCH ON THE INTEGRATION OF VIRTUAL REALITY INTO INDUSTRIAL DESIGN EDUCATION

Ph.D. THESIS

Ahmet HAMURCU

Department of Industrial Product Design

Industrial Product Design Programme

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Ahmet HAMURCU
(502142901)

Department of Industrial Product Design

Industrial Product Design Programme

Thesis Advisor: Prof. Dr. Şebnem TİMUR
Thesis Co-Advisor: Prof. Dr. Kerem RIZVANOĞLU

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DOKTORA TEZİ

Ahmet HAMURCU
(502142901)

Endüstri Ürünleri Tasarımı Anabilim Dalı

Endüstri Ürünleri Tasarımı Programı

Tez Danışmanı: Prof. Dr. Şebnem TİMUR
Eş Danışman: Prof. Dr. Kerem RIZVANOĞLU

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Ahmet HAMURCU, a Ph.D. student of ITU Graduate School student ID 502142901, successfully defended the thesis/dissertation entitled “AN ACTION RESEARCH ON THE INTEGRATION OF VIRTUAL REALITY INTO INDUSTRIAL DESIGN EDUCATION”, which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Prof. Dr. Şebnem TİMUR** Istanbul Technical University	.....
Co-advisor :	**Prof. Dr. Kerem RIZVANOĞLU** Galatasaray University	.....
Jury Members :	**Assoc. Prof. Dr. Gökhan İNCE** Istanbul Technical University	.....
	Assoc. Prof. Dr. A. Selami ÇİFTER Mimar Sinan Fine Arts University	.....
	Asst. Prof. Dr. Ekrem Cem ALPPAY Istanbul Technical University	.....
	Asst. Prof. Dr. Elif KÜÇÜKSAYRAÇ Istanbul Technical University	.....
	Assoc. Prof. Dr. Asım Evren YANTAÇ Koç University	.....

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To my wife and family,

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Ahmet HAMURCU
(Industrial Designer)

TABLE OF CONTENTS

Page

FOREWORD ..... **ix**
TABLE OF CONTENTS ..... **xi**
ABBREVIATIONS ..... **xv**
LIST OF TABLES ..... **xvii**
LIST OF FIGURES ..... **xxi**
SUMMARY ..... **xxvii**
ÖZET ..... **xxxi**
1. INTRODUCTION **1**
1.1 Problem Statement and Research Question 1
1.2 Aim and Scope of the Study 6
1.3 Thesis Structure 8
2. LITERATURE REVIEW **11**
2.1 Industrial Design Processes in Practice and Education 11
2.1.1 Definitions of design and industrial design 11
2.1.2 Industrial design process 13
2.1.3 Industrial design within new product development 19
2.1.4 Design representations within industrial design practice 19
2.1.5 Industrial design education 23
2.1.5.1 Main studio-based practices of industrial design education: studio critiques 23
2.1.5.2 Core tasks of students: representing and presenting design ideas 26
2.2 Virtual Reality 27
2.2.1 Definitions of virtual reality 27
2.2.2 Virtual reality within reality technologies 28
2.2.3 Key elements of virtual reality experience 29
2.2.4 Common types of virtual reality 30
2.2.5 Taxonomy of virtual reality systems 31
2.2.6 Hardware and software in virtual reality systems 36
2.2.6.1 Hardware 36
2.2.6.2 Software 40
2.3 Possible Applications of Virtual Reality in Design Processes 40
2.4 Summary 46
3. THEORETICAL FRAMEWORK **49**
3.1 Designing and Virtual Reality within The Perspective of Design Theory 49
3.2 Design Representation and Virtual Reality within The Perspective of Communication Theory 52
3.3 Technology Acceptance Models and Theories 54
3.3.1 Technology acceptance models 55
3.3.1.1 Model of PC utilization (MPCU) 55
3.3.1.2 Technology acceptance model (TAM) 57
3.3.1.3 Combined TAM and TPB (C-TAM-TPB) 57
3.3.1.4 Extended technology acceptance model (TAM2) 58

3.3.1.5 Technology acceptance model 3 (TAM3) 59
3.3.2 Technology acceptance theories 60
3.3.2.1 Unified theory of acceptance and use of technology (UTAUT) 61
3.3.2.2 Extended unified theory of acceptance and use of technology (UTAUT2) 61
3.3.3 Comparison of technology acceptance models and theories 63
3.4 Product Acceptance Models 63
3.4.1 Shackel's product acceptance model 64
3.4.2 Nielsen's product acceptance model 64
3.5 Summary 65
4. METHODOLOGY 67
4.1 Research Design and Approach 67
4.2 Methodological Framework 71
4.3 Validity, Reliability, and Generalizability of The Study 74
4.3.1 Validity of the study 76
4.3.2 Reliability of the study 78
4.3.3 Generalizability of the study 80
4.4 Ethical Issues 81
5. PROCEDURES, METHODS AND FINDINGS OF THE RESEARCH 83
5.1 First Stage: Initial Investigations 83
5.1.1 Systematic literature review on related works 83
5.1.2 Preliminary study 88
5.1.2.1 Procedure and method 88
5.1.2.2 Analyses of the collected data 97
5.1.3 Critical outcomes of initial investigations 111
5.2 Second Stage: Integration of Virtual Reality 112
5.2.1 Planning the general framework of the in-studio study 112
5.2.2 Description of the selected industrial design studio course 120
5.2.3 Brief of the selected project 122
5.2.4 Integration of the research process into the project process 123
5.2.5 Mandatory use of VR in the jury sessions 133
5.2.5.1 The 2nd preliminary jury session: the 1st cycle of mandatory use 133
Plan: planning the 2nd preliminary jury session 133
Act: performing the 2nd preliminary jury session by using VR 136
Observe: questioning what happened in the 2nd preliminary jury session 141
Reflect: reflecting on the findings of the 1st cycle of mandatory use 148
5.2.5.2 The 3rd preliminary jury session: the 2nd cycle of mandatory use 149
Plan: planning the 3rd preliminary jury session 149
Act: performing the 3rd preliminary jury session by using VR 153
Observe: questioning what happened in the 3rd preliminary jury session 156
Reflect: reflecting on the findings of the 2nd cycle of mandatory use 166
5.2.5.3 The final jury session: the 3rd cycle of mandatory use 167
Plan: planning the final jury session 167
Act: performing the final jury session by using VR 170
Observe: questioning what happened in the final jury session 170
Reflect: reflecting on the findings of the 3rd cycle of mandatory use 180
5.2.6 Voluntary use of VR in other practices 181
5.2.6.1 Plan: planning the voluntary use of VR 181

5.2.6.2 Act: making VR available for students and instructors 181
5.2.6.3 Observe: questioning what happened throughout the project process 182
5.2.6.4 Reflect: reflecting on the findings of the voluntary use of VR 185
5.3 Third Stage: Final Investigations 185
5.3.1 Familiarity with the technology used in this research 187
5.3.2 Usability level of the proposed way of VR use in the final jury session for using VR in the jury practices of industrial design education 189
5.3.3 Final assessments of students and instructors on the VR technology they used during the project process and its use in industrial design studio courses 192
5.3.4 Reasons why VR technology was not used in other practices and activities where students and instructors got involved together 208
5.4 Summary 209
6. CONCLUSIONS 221
6.1 General Overview and Final Remarks 221
6.2 Conclusions of the Study 227
6.2.1 Key Conclusions of the Study 227
6.2.2 Overall Conclusion of the Study 236
6.3 Contributions of the Study 238
6.4 Limitations of the Study 239
6.5 Recommendations for Further Studies 240
REFERENCES 243
APPENDICES 265
CURRICULUM VITAE 325

ABBREVIATIONS

2D : Two-dimensional
3D : Three-dimensional
APA : American Psychological Association
AR : Augmented Reality
ASQ : After Scenario Questionnaire
AV : Augmented Virtuality
BI : Behavioral Intention
BSI : British Standards Institution
C-TAM-TPB : Combined TAM and TPB
CAD : Computer Aided Design
CDT : Cognitive Dissonance Theory
CHM : Computer History Museum
DOI : Diffusion of Innovation
doi : Digital Object Identifier
DTI : Department of Trade and Industry (in the United Kingdom)
EDT : Expectation-Disconfirmation Theory
EE : Effort Expectancy
ETMK : Industrial Designers' Society of Turkey
FC : Facilitating Conditions
H : Habit
HCI : Human-Computer Interaction
HM : Hedonic Motivation
ICF : Informed Consent Form
ICSID : International Council of Societies of Industrial Design
ID : Industrial Design
IDF : Interaction Design Foundation
IDSA : Industrial Designers Society of America
IDT : Innovation Diffusion Theory
ISO : International Organization for Standardization
ITU : Istanbul Technical University
iVP : **i**nteractive Virtual Prototype
MM : Motivational Model
MPCU : Model of PC Utilization
MR : Mixed Reality
NASA-TLX : NASA Task Load Index
NASAD : National Association of Schools of Art and Design
NPD : New Product Development
NPS : Net Promoter Score
PCWTA : Public Child Welfare Training Academy
PE : Performance Expectancy
PV : Price Value
SCT : Social Cognitive Theory
SEQ : Single Ease Question
SI : Social Influence

SMEQ : Subjective Mental Effort Questionnaire
SUS : System Usability Scale
TAM : Technology Acceptance Model
TAM2 : Extended Technology Acceptance Model
TAM3 : Technology Acceptance Model 3
TPB : Theory of Planned Behavior
TRA : Theory of Reasoned Action
UME : Usability Magnitude Estimation
UTAUT : Unified Theory of Acceptance and Use of Technology
UTAUT2 : Extended Unified Theory of Acceptance and Use of Technology
VR : Virtual Reality
VRP : Virtual Reality Prototype
WDO : World Design Organization

LIST OF TABLES

Page

Table 2.1 : Some other descriptions of "design" and "designing" in the literature. . **12**
Table 2.2 : Design process models. **17**
Table 2.3 : Classification of visual design representations. **21**
Table 2.4 : Uses of visual design representations. **22**
Table 2.5 : Eight phases of the design jury session by Roberts (2004). **25**
Table 3.1 : Base theories for technology acceptance. **55**
Table 3.2 : Comparison of technology acceptance models and theories. **63**
Table 4.1 : A comparison of quantitative and qualitative research approaches. **68**
Table 4.2 : Common research method/ologies in alphabetical order. **71**
Table 4.3 : Summary table of the methods used in the study. **75**
Table 4.4 : Validity, reliability and generalizability in qualitative research and alternative terminologies associated with them. **76**
Table 4.5 : The major differences between positivism and interpretivism. **77**
Table 4.6 : Descriptions of three common threats on validity in qualitative research. **79**
Table 4.7 : Commonly used strategies to deal with threats on validity and their brief descriptions. **79**
Table 4.8 : The effects of the strategies to deal with the threats on reactivity, researcher and respondent biases. **79**
Table 5.1 : VR use types in professional practice-related studies. **86**
Table 5.2 : The studies related to the use of VR technology in industrial design education. **87**
Table 5.3 : Scale items of the questionnaire. **95**
Table 5.4 : Differences between the focus group and group discussion. **96**
Table 5.5 : Gender distribution of participants. **97**
Table 5.6 : Grade distribution of students. **97**
Table 5.7 : Means and standard deviations of scale items (N=38). **98**
Table 5.8 : Glossary of terms used in the hands-on guide of content analysis. **101**
Table 5.9 : Some questions that needed to be answered when planning the in-studio study and their bases from some critical outcomes. **111**
Table 5.10 : Decisions taken for planning the general framework of the in-studio study and reasons behind. **119**
Table 5.11 : The project schedule presented in the project brief. **124**
Table 5.12 : Age and gender distributions of the project groups. **127**
Table 5.13 : Summary of examined usability surveys. **130**
Table 5.14 : The original SUS items and how they were modified for measuring the usability level of the intermediary software. **131**
Table 5.15 : Design representation tool use of industrial design students to present and explain product aspects. **134**
Table 5.16 : Percentages of the most difficult design tasks as identified by students by course year, gender, and school; results of Chi square tests. **135**

Table 5.17 : Jury durations of the project groups and the durations of experiencing the VR scenes during the jury session. **143**
Table 5.18 : Students' responses to the questions regarding the process of creating their CAD models and turning them into a VR scene. **148**
Table 5.19 : Jury durations of the project groups and the durations of experiencing the VR scenes during the jury session in the 3rd preliminary jury. **158**
Table 5.20 : Questions asked to jurors and students in the second-round interviews. **161**
Table 5.21 : Jury durations of the project groups and the durations of VR use of groups and jurors during the jury sessions in the final jury. **175**
Table 5.22 : Questions asked to jurors and students in the third-round interviews. **179**
Table 5.23 : Questionnaire items related to technology familiarity. **188**
Table 5.24 : Original SUS items and how they were modified for measuring the usability level of the proposed way of VR use in the final jury session. **190**
Table 5.25 : Original items of UTAUT2 and NPS and how they were modified for this part of the research. **193**
Table A.1 : Creative process models. **266**
Table A.2 : Details about 2D Visual Design Representations. **268**
Table A.3 : Details about 3D Visual Design Representations. **271**
Table A.4 : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study). **274**
Table A.5 : VR use types in professional practice-related studies. **283**
Table A.6 : The studies related to the use of VR in industrial design education. ... **283**
Table F.1 : An excerpt related to prejudgments about VR use in the jury session. **308**
Table F.2 : Excerpts related to the effects of VR use in the jury session on the motivations and performances of the students. **308**
Table F.3 : Excerpts related to the effects of using VR in the jury session on the design sheets of the students. **308**
Table F.4 : Excerpts related to the effects of VR use in the jury session on the design evaluation of jurors. **309**
Table F.5 : Excerpts related to the effects of VR use in the jury session on the communication between the jurors and both the students and the designs. **310**
Table F.6 : Excerpts related to why the jurors needed to experience some of the VR scenes. **310**
Table F.7 : Excerpts related to why the jurors experienced only a few of the VR scenes, not all of them. **311**
Table F.8 : Excerpts related to students' feels and thoughts that emerged when their VR scenes were not experienced by one juror or more than one juror. **311**
Table F.9 : An excerpt related to why the jury members used the VR headset by holding it like binoculars with one hand rather than by wearing it properly. **312**
Table F.10 : Excerpts related to the comparison of evaluating a design by watching it in a video animation or experiencing it in a VR scene. **312**
Table F.11 : Excerpts related to the way of VR use in this jury session, and demands for the next jury session. **313**
Table F.12 : Excerpts related to the comparison of the proposed ways of VR use in the first and second cycle. **314**

Table F.13 : Excerpts from the jurors' responses to the second question in Table 5.20. ..... **315**
Table F.14 : Excerpts from the students' responses to the second question in Table 5.20. ..... **315**
Table F.15 : Excerpts from the responses to the fifth question in Table 5.20. ..... **316**
Table F.16 : Excerpts related to the jurors VR equipment preferences. **317**
Table F.17 : Excerpts related to whether the shared use of mobile VR equipment caused any trouble. **317**
Table F.18 : Excerpts related to why the jurors needed to experience the VR scenes in this jury session. **318**
Table F.19 : Excerpts related to demands for the next jury session. **318**
Table F.20 : Excerpts related to the comparison of the proposed ways of VR use in the final jury session and the previous one. **319**
Table F.21 : Excerpts related to whether VR was well integrated into the jury practice in the final jury session. **321**
Table F.22 : Excerpts related to the use of physical models and mock-ups in the final jury session. **322**
Table F.23 : Excerpts related to whether being wondered what a juror saw and/or where s/he looked in a VR scene while s/he was experiencing it by using the mobile VR glasses. **323**

LIST OF FIGURES

Page

Figure 1.1 : Major changes in computer technology and their reflections on the representative tools of industrial design. **2**
Figure 1.2 : A generic schematization of the production ways commonly used for creating design representation in industrial design education. **4**
Figure 1.3 : Commonly used production and presentation ways of design representations by industrial design students. **5**
Figure 1.4 : Scope of the study. **8**
Figure 1.5 : Structure of the thesis. **9**
Figure 2.1 : Some of the frequently cited models in the literature: (a) Jones's model (Jones, 1992), (b) French's model (French, 1985), (c) Archer's model (L. B. Archer, 1965), (d) Pahl and Beitz's model (Cross, 2000, p. 37), (e) Pugh's model (Pugh, 1991, p. 11). **14**
Figure 2.2 : Types of design process models. **16**
Figure 2.3 : Industrial design process within the new product development process. **19**
Figure 2.4 : Evolution of the product cycle. **20**
Figure 2.5 : Updated version of the virtuality continuum of Milgram & Kishino (1994). **28**
Figure 2.6 : Examples of commercially available VR/AV/AR/MR systems and technology providers. **29**
Figure 2.7 : Taxonomy of virtual reality systems. **32**
Figure 2.8 : An example of hand-based VR systems. **32**
Figure 2.9 : An example of monitor-based VR systems. **32**
Figure 2.10 : An example of enhanced wall projectors. **33**
Figure 2.11 : ImmersaDesk. **33**
Figure 2.12 : An example of monocular head-based systems. **34**
Figure 2.13 : An example of binocular head-based systems. **34**
Figure 2.14 : An example of vehicle simulations. **35**
Figure 2.15 : CAVE (Cave Automatic Virtual Environment). **35**
Figure 2.16 : Taxonomy of the VR input devices. **37**
Figure 2.17 : Taxonomy of VR/AR input devices. **38**
Figure 2.18 : Taxonomy of input devices in VR systems. **39**
Figure 2.19 : Taxonomy of the VR output devices. **41**
Figure 2.20 : Taxonomy of VR/AR output devices. **42**
Figure 2.21 : Taxonomy of output devices in VR systems. **43**
Figure 2.22 : Possible applications of virtual reality in design processes. **44**
Figure 3.1 : Relations between the industrial design process and VR. **51**
Figure 3.2 : Three communication models: (a) Shannon (2001) (Shannon–Weaver model), (b) Schramm (1971), (c) Maletzke (1981). **53**
Figure 3.3 : Three design-specific communication models: (a) Maser (1976), (b) Krippendorff & Butter (1984), (c) Monö (1997). **54**
Figure 3.4 : Model of PC Utilization (MPCU). **56**

Figure 3.5 : Technology Acceptance Model (TAM). **57**
Figure 3.6 : Combined TAM and TPB (C-TAM-TPB). **58**
Figure 3.7 : Extended Technology Acceptance Model (TAM2). **59**
Figure 3.8 : Technology Acceptance Model 3 (TAM3). **60**
Figure 3.9 : Unified Theory of Acceptance and Use of Technology (UTAUT). **62**
Figure 3.10 : Extended Unified Theory of Acceptance and Use of Technology (UTAUT2). **62**
Figure 3.11 : Shackel (1991)'s product acceptance model. **64**
Figure 3.12 : Nielsen (1993)'s product acceptability model. **65**
Figure 3.13 : Core components of user experience. **65**
Figure 3.14 : Schematized summary of the theoretical framework of the study. **66**
Figure 4.1 : Research design of the study. **70**
Figure 4.2 : The generic process of action research. **72**
Figure 4.3 : Methodological framework of the research. **74**
Figure 5.1 : The stacked column chart of the selected studies by years. **85**
Figure 5.2 : The stacked column chart of the ID-focused studies by years. **85**
Figure 5.3 : Types of handling of VR in VR-focused studies. **85**
Figure 5.4 : Locations of VR stations in the hall. **89**
Figure 5.5 : Presentations of Evren Arın (up) and Çetin Yıldırım (down). **89**
Figure 5.6 : A participant trying Vred software. **90**
Figure 5.7 : A participant experiencing the 3D model in the VR environment. **90**
Figure 5.8 : Participants filling out the online questionnaire. **91**
Figure 5.9 : A frame from the discussion session. **91**
Figure 5.10 : Ratings of participants' familiarity with the VR headsets. **97**
Figure 5.11 : Categorized radar graphs of the items' results. **99**
Figure 5.12 : Example of content analysis leading to higher levels of abstraction from manifest to latent content. **101**
Figure 5.13 : Results of the quantitative content analysis of all participants' written and verbal data. **103**
Figure 5.14 : Results of the quantitative content analysis of the instructors' verbal and written data. **104**
Figure 5.15 : Results of the quantitative content analysis of the students' verbal and written data. **105**
Figure 5.16 : VR technology through potential users' eyes in terms of "Design Representation". **107**
Figure 5.17 : VR technology through potential users' eyes in terms of "Design Evaluation". **107**
Figure 5.18 : VR technology through potential users' eyes in terms of "Design Development". **107**
Figure 5.19 : VR technology through potential users' eyes in terms of "Design Presentation". **108**
Figure 5.20 : VR technology through potential users' eyes in terms of "Design Process". **108**
Figure 5.21 : VR technology through potential users' eyes in terms of "Collaboration". **108**
Figure 5.22 : VR technology through potential users' eyes in terms of "Competency Development of Students". **109**
Figure 5.23 : VR technology through potential users' eyes in terms of "Performance of Students". **109**

Figure 5.24 : VR technology through potential users' eyes in terms of "Maturity Level of Technology". **109**
Figure 5.25 : VR technology through potential users' eyes in terms of "Individual Use". **109**
Figure 5.26 : VR technology through potential users' eyes in terms of "Educational Use". **110**
Figure 5.27 : The illustration of the transition between the use of hand sketching and CAD to represent design ideas during the progression of the design process. **114**
Figure 5.28 : A comparison of the VR devices reviewed for this study. **115**
Figure 5.29 : A figure showing the tracking and mobility performances of the VR devices reviewed for this study. **115**
Figure 5.30 : CAD software which SimLab Composer 8.0 is compatible with. **116**
Figure 5.31 : An example of a CAD software interface into which SimLab Composer 8.0 was embedded (Rhinoceros interface). **117**
Figure 5.32 : The human figure using to set the starting position of the camera in the VR scene in SimLab Composer 8.0. ..... **117**
Figure 5.33 : An example of viewing a CAD model in the VR scene with the desktop mode of SimLab Composer 8.0. ..... **118**
Figure 5.34 : Relationship between the course and Industrial Product Design Program. **121**
Figure 5.35 : Integration of the action research process into the project process. **125**
Figure 5.36 : Introducing and teaching the VR equipment and software to be used. **128**
Figure 5.37 : A photo taken while a student was performing the given task and the screenshot of the computer screen at that moment. **132**
Figure 5.38 : Associating SUS scores with percentile rank and letter grades. **132**
Figure 5.39 : The regular seating plan of studio 217B. **136**
Figure 5.40 : Rearranging the seating plan for the 2nd preliminary jury session. **137**
Figure 5.41 : The use of three chairs as a barrier to prevent students or others from tripping over the cables of Base Station 2. ..... **138**
Figure 5.42 : Changes made in the jury setup layout during the jury session: (a) is the proposed layout, (b) and (c) are the changes respectively made in the layout in line with the juror's demands. **139**
Figure 5.43 : Photos showing the proposed jury setup with VR and the changes made in it during the jury session. **140**
Figure 5.44 : Screenshots from the VR scenes submitted for the second preliminary jury. **142**
Figure 5.45 : Some photos that show how the jurors use the VR headset. **144**
Figure 5.46 : Proposed jury setup layout for the 3rd preliminary jury session. **150**
Figure 5.47 : VR Box mobile VR glasses. **151**
Figure 5.48 : Changes made in the jury setup layout immediately before the jury session: (a) is the proposed layout and (b) is the changed version of the layout. **154**
Figure 5.49 : Photos showing the jury setup in the 3rd preliminary jury session and the way of using VR by the jurors within it. **155**
Figure 5.50 : Smartphones of jury members and the researcher. **155**
Figure 5.51 : Screenshots from the VR scenes submitted for the third preliminary jury. **157**

Figure 5.52 : Two photos showing how jurors gave feedback on the critical issues that they detected in the VR environment. **159**
Figure 5.53 : Some photos showing how the jurors use mobile VR glasses. **159**
Figure 5.54 : Responses to the question 3 and 4 in Table 5.20. ..... **164**
Figure 5.55 : Proposed jury setup layout for the final jury session. **168**
Figure 5.56 : Photos showing the jury setup in the final jury session, and the way of using VR, design sheets (digital and non-digital), and physical models within it. **171**
Figure 5.57 : Screenshots from the VR scenes submitted for the third preliminary jury. **173**
Figure 5.58 : The ratio of the durations of VR use in the jury sessions of the groups to the total jury duration of the groups. **174**
Figure 5.59 : A photo showing how the group member in the VR environment tapped accidentally on the arm of his group mate who is giving the oral presentation with the control stick of the HTC Vive. **175**
Figure 5.60 : A photo showing how the group member in the VR environment accidentally hit the screen of Laptop 1 with the control stick of the HTC Vive. **176**
Figure 5.61 : A photo showing the use of the 1/10 scale physical model by Group 5 for presentation purposes. **176**
Figure 5.62 : Photos showing the use of the 1/1 scale physical mock-ups by Group 8 and 9 for presentation purposes. **176**
Figure 5.63 : Photos showing how the 1/10 scale physical models of Group 3, 5, and 7 were examined by the jurors. **177**
Figure 5.64 : Photos showing how the 1/1 scale physical mock-ups of Group 3 and 8 were examined by the jurors. **178**
Figure 5.65 : A screenshot from the CAD model shared with students and instructors by the firm. **182**
Figure 5.66 : Some photos showing how students and instructors tried to imagine and apprehend the borders of the interior of a minibus by using tape drawing and role-playing methods. **183**
Figure 5.67 : An example of the desk-critique sessions carried out by using CAD models. **184**
Figure 5.68 : Some photos showing how the HTC Vive VR setup was used by students. **185**
Figure 5.69 : Some photos showing how students tried to eliminate the shortage of physical interaction with the seating unit and grab bars in their virtual model. **186**
Figure 5.70 : Participants' previous familiarity status with the technology used in this research. **189**
Figure 5.71 : The radar graphs of the responses to the SUS items in the questionnaire. **191**
Figure 5.72 : Curved grading scale interpretation of SUS scores. **192**
Figure 5.73 : The graphical representations of the responses to Performance Expectancy items. **198**
Figure 5.74 : The graphical representations of the responses to Effort Expectancy items. **199**
Figure 5.75 : The graphical representations of the responses to Facilitating Conditions items. **201**

Figure 5.76 : The graphical representations of the responses to Hedonic Motivation and Behavioral Intention items. **202**
Figure 5.77 : The graphical representation of participants' responses to the Net Promoter Score item. **203**
Figure 5.78 : The schematic representation of the second stage. **215**
Figure 6.1 : The schematized summary of the research process. **228**
Figure 6.2 : A brief comparison of the attempts in this thesis study to integrate VR technology into the jury practice of industrial design education. **233**
Figure A.1 : The stacked column chart of the selected studies by years. **282**
Figure A.2 : The stacked column chart of the ID-focused studies by years. **282**
Figure A.3 : Types of handling of VR in VR-focused studies. **282**
Figure C.1 : Pages of the project brief. **287**
Figure C.2 : Pages of the Informed Consent Form. **292**
Figure C.3 : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices. **295**
Figure C.4 : Consent form for the use of personal data. **301**
Figure D.1 : The approval of ITU Humanities and Social Sciences Committee of Human Research Ethics. **302**
Figure D.2 : The approval of ITU Health and Engineering Sciences Human Research Ethics Committee. **303**
Figure E.1 : Pages of the catalogue form of the course "EUT 320E Industrial Design Studio III". **304**

AN ACTION RESEARCH ON THE INTEGRATION OF VIRTUAL REALITY INTO INDUSTRIAL DESIGN EDUCATION

SUMMARY

Industrial designers have always tended to use computers and computer-based technologies that they believe will help them do their works better and easier, and thereby, they quickly adopted them. Also, these technologies adopted by professionals have usually been used by industrial design students and/or educators and they were integrated into industrial design education shortly after their adoptions because it is conducted as a simulation of professional life. However, although Virtual Reality (VR) technology that is one of the computer-based technologies has become economically available for designers with the release of VR headsets such as HTC Vive and Oculus Rift in 2016, and has already been adopted by professionals, how it can be integrated into industrial design education is still unclear. Moving from this point of view, this thesis explores how VR technology can be integrated into industrial design education. For this purpose, an action research was conducted by trying to use it under the real conditions of an industrial design studio course.

In the first step of the research, a systematic literature review on related works in addition to the general literature review and a preliminary study with prospective users (industrial design students and instructors) were carried out to reveal (i) what the former studies regarding the use of VR technology in industrial design education are; (ii) what these studies say about this issue; and (iii) what the opinions of potential users, who are industrial design students and instructors, about the use of VR technology in industrial design education are.

The systematic literature review showed that VR technology was tried to be used before in the professional practices of industrial design as: a usability evaluation tool; an ergonomic evaluation tool; a visualization tool; a product demonstration tool; a presentation tool; an interactive prototyping tool; an immersive mood board; a sketching tool; and a collaboration tool. However, none of these types of use was tried to be employed before under the real conditions of the educational setting of an industrial design studio course.

The preliminary study was conducted with industrial design students and instructors who came from 10 universities in Turkey. In this preliminary study, first, VR technology was introduced to the participants. Then, it was experienced by the participants. And then, both quantitative and qualitative data based on their opinions were collected and analyzed.

The results of the preliminary study revealed that: (i) potential users are eager to use VR technology; (ii) however, they have reservations as well as their positive opinions about using it in industrial design studio courses; and (iii) almost all these reservations are related to its usability.

In the second step, an in-studio study was planned based on the findings of these studies, and with a focus on getting started by eliminating or by minimizing these reservations as much as possible.

In the third step, in line with this planning, VR technology was tried to be used in the studio-based practices of an industrial design studio course. This in-studio study was carried out in the course "EUT 320E Industrial Product Design III" with the project issue "Smart Electric Minibus Design for Anadolu Isuzu". This course was the 3rd year industrial design studio course of Istanbul Technical University (ITU) Department of Industrial Design, which was conducted in the 2017-2018 spring semester. In this process where the course process and the research process merged, the researcher worked: as one of the instructors of the course; as an operator who is responsible for installing and running the VR system properly, and responsible for its being used easily and hygienically; as an educator who will meet the learning need for VR.

In the in-studio study, (i) how VR technology can be integrated into the jury practices of industrial design education was questioned by making the use of it mandatory by students for design representation and presentation purposes, and then, by trying to use it in the jury sessions; and (ii) how it can be integrated into other studio-based practices of industrial design education was questioned by making it available for use during the studio hours of the course, and then, by observing whether it will be used for/in other studio-based practices.

Throughout the project process of the course, it was attempted three times to integrate VR technology into the jury practices of the course. In the last attempt, this was achieved. Each attempt was scrutinized with the observations recorded during the jury sessions and the interviews with the user groups after the jury sessions. The interviews with the students were held as group interviews, whereas the interviews with the instructor-jurors were held one-to-one. Since it was not possible to hold face-to-face interviews with the invited jury members, their opinions were tried to be gotten via e-mail. These attempts and examinations show step-by-step how VR technology can be integrated into the jury practice of industrial design education by developing solutions in line with the needs and demands of students and instructors.

On the other hand, it was observed that (i) making VR available for use during the studio hours and giving a short training on how to use its hardware and software opened the way of using it as a design evaluation tool by students; and (ii) neither students nor instructors demanded or attempted to use VR in other practices and activities where students and instructors got involved together.

In the last step, considering the results of the in-studio study, (i) the usability level of the proposed way for using VR technology in the final jury session was measured with the help of the System Usability Scale (SUS); (ii) the final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design were revealed with the help of the interviews with students and instructors and the questionnaire items adapted from the scale items of the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) and the Net Promoter Score (NPS); and (iii) the reasons why VR technology was not used in other practices and activities where students and instructors got involved together were questioned with the help of interviews with students and instructors.

The SUS score was calculated as 71.3. This score indicates that the usability of the last proposal for using VR technology in the jury practices of industrial design education is OK but can be improved.

Besides, the final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design revealed that although they found VR technology useful in various aspects and easy to use at various degrees, they still had some reservations in their minds. However, this time, these reservations were based upon (i) whether the facilitating conditions about the frequent or the continuous use of VR technology were sufficiently present; and (ii) the thought that using it for evaluating designs of small products will not be so useful.

On the other hand, it was seen that the reasons why VR technology was not used in other practices and activities where students and instructors got involved together were related to (i) not having yet sufficient familiarity and mastery of its use in such activities and practices; (ii) perceiving VR as a technology that would only enable to evaluate and/or present the whole – not the parts – of a design over a finished model; and (iii) not being its set-up ready for use when needed.

In addition to all these, participants stated that for the use of VR technology in industrial design education to be sustainable, (i) it should be easily accessible and usable for both students and instructors with a permanent installation in the studio environment; (ii) it should be led/managed by at least one instructor/executive; and (iii) the requirements of the technology such as installation/setup, learning, operating, and maintenance requirements should be met by at least one technical person/expert/operator.

As a result, this thesis study contributes to the relevant literature (i) by showing, step-by-step, one of the ways of integrating VR technology into the jury practice of industrial design education; (ii) by revealing the clues of how it can be integrated into other studio-based practices of industrial design education; and (iii) by outlining what might be the possible attitudes of industrial design students and instructors towards the use of VR technology in industrial design studio courses before and after the actual use of it in those courses.

This thesis study is one of the first attempts in the literature to integrate VR technology into industrial design education by trying to use it under the real conditions of an industrial design studio course. Hence, its outcomes need to be verified and/or improved with similar studies. Besides, how it can be integrated into other studio-based practices of industrial design education is still not clear enough because the relevant part of the study has been conducted with an unstructured intervention. Therefore, it should be noted that there is also need for further studies to be carried out with structured interventions on this issue.

SANAL GERÇEKLİĞİN ENDÜSTRİYEL TASARIM EĞİTİMİNE ENTEGRASYONU ÜZERİNE BİR EYLEM ARAŞTIRMASI

ÖZET

Endüstriyel tasarımcılar, işlerini daha iyi ve daha kolay yapmalarına yardımcı olacağına inandıkları bilgisayarları ve bilgisayar tabanlı teknolojileri her zaman kullanma eğiliminde olmuşlar ve bu teknolojileri kullanmayı hızla benimsemişlerdir. Genellikle, profesyoneller tarafından kullanılmaya başlanan bu teknolojilerin kısa süre içerisinde endüstriyel tasarım öğrencileri ve eğitmenleri tarafından da kullanılmaya başlanarak endüstriyel tasarım eğitimine bir şekilde entegre olduğu görülmektedir. Bu durum, endüstriyel tasarım eğitiminin profesyonel hayatın bir simülasyonu olarak yürütülmesinden dolayı oldukça olağan bir süreç olarak değerlendirilebilir. Ancak, bilgisayar tabanlı teknolojilerden biri olan 'Sanal Gerçeklik' (SG) için aynı durumdan söz etmek mümkün değildir. Çünkü, 'Sanal Gerçeklik', HTC Vive ve Oculus Rift gibi sanal gerçeklik gözlüklerinin 2016 yılında piyasaya sürülmesiyle birlikte, endüstriyel tasarımcılar için ekonomik olarak erişilebilir hale gelmiş ve profesyonel tasarımcılar tarafından kullanılması hızla benimsenmiştir; ama bu teknolojinin endüstriyel tasarım eğitimine nasıl entegre olacağı halen belirsizliğini korumaktadır. Bu durumdan hareketle, bu tez çalışması SG teknolojisinin endüstriyel tasarım eğitimine nasıl entegre edilebileceğini araştırmaktadır ve bu amaç doğrultusunda, bir endüstriyel tasarım stüdyosu dersinin gerçek koşulları altında bu teknoloji kullanılmaya çalışılarak bir eylem araştırması yürütülmüştür.

Araştırma sürecinin ilk adımında, geniş ve kapsamlı bir literatüre taramasına ilaveten konuyla ilişkili çalışmalar üzerine sistematik bir literatür taraması ve muhtemel kullanıcılarla (endüstriyel tasarım öğrencileri ve eğitmenleriyle) bir ön çalışma yapılmıştır. Sistematik literatür taraması ile SG teknolojisinin endüstriyel tasarım eğitiminde kullanımına dair önceki çalışmaların neler olduğu ve bu çalışmaların araştırma konusu hakkında neler söylediği ortaya çıkarılmaya çalışılmıştır. Potansiyel kullanıcılarla yapılan ön çalışma ise endüstriyel tasarım öğrencileri ve eğitmenlerinin SG teknolojisinin endüstriyel tasarım eğitiminde kullanılması hakkında neler düşündüklerini ortaya çıkarmayı amaçlamıştır.

Sistematik literatür taraması göstermiştir ki, SG teknolojisi, endüstriyel tasarımın profesyonel pratiğinde – bundan önceki süreçte – kullanılabilirlik değerlendirme aracı, ergonomik değerlendirme aracı, görselleştirme aracı, ürün demonstrasyon aracı, sunum aracı, etkileşimli prototip oluşturma aracı, kuşatıcı "mood board" aracı, eskiz aracı ve iş birliği aracı olarak kullanılmaya çalışılmıştır. Fakat, bu kullanım türlerinin hiçbirisi bir endüstriyel tasarım stüdyosu dersinin gerçek koşulları altında kullanılmaya çalışılmamıştır.

Ön çalışma ise, Türkiye'deki 10 üniversiteden gelen endüstriyel tasarım öğrencileri ve eğitmenleri ile gerçekleştirilmiştir. Bu ön çalışmada, öncelikle katılımcılara SG teknolojisi tanıtılmış, ardından bu teknolojiyi deneyimlemeleri sağlanmıştır. Sonrasında ise katılımcıların görüşlerine dair hem kantitatif hem de kalitatif veri toplanmıştır.

Ön çalışmanın sonuçları,

(i) Potansiyel kullanıcıların SG teknolojisini kullanmaya istekli olduklarını,
(ii) Ancak bu teknolojinin endüstriyel tasarım stüdyosu derslerinde kullanılması konusunda pozitif düşünceleri olduğu kadar çekincelerinin de olduğunu, ve
(iii) Bu çekincelerin neredeyse tamamının onun kullanılabilirliği ile ilgili olduğunu

ortaya çıkarmıştır.

Araştırma sürecinin ikinci adımında, bu çalışmalardan elde edilen bulgular ışığında tespit edilen çekincelerin mümkün olduğunca ortadan kaldırılmasına ya da en aza indirilmesine odaklı olarak bir stüdyo içi çalışma planlanmıştır.

Üçüncü adımda ise, yapılan planlamaya uyularak SG teknolojisi bir endüstriyel tasarım stüdyosu dersinin stüdyo tabanlı pratiklerinde kullanılmaya çalışılmıştır. Bu stüdyo içi çalışma, İstanbul Teknik Üniversitesi (İTÜ) Endüstriyel Tasarım Bölümünün 2017-2018 bahar döneminde "Anadolu Isuzu firması için elektrikli akıllı minibüs tasarımı" başlıklı proje konusu ile yürütülmüş olan "EUT 320E Endüstriyel Ürün Tasarımı III" isimli derste gerçekleştirilmiştir. Araştırma süreci ile ders sürecinin iç içe geçtiği bu süreçte araştırmacı, hem dersin eğitmenlerinden birisi, hem SG sisteminin düzgün bir şekilde kurulmasından, çalıştırılmasından, kolay ve hijyenik bir şekilde kullanılmasından sorumlu bir operatör, hem de SG'nin öğrenme ihtiyacını karşılayacak bir eğitimci olarak yer almıştır.

Stüdyo içi çalışmada,

(i) SG teknolojisinin endüstriyel tasarımın jüri pratiklerine nasıl entegre edilebileceği, bu teknolojinin öğrenciler tarafından tasarım temsili ve sunumu amacıyla kullanımı zorunlu hale getirilip jüri oturumlarında kullanılmaya çalışılması ile,
(ii) SG teknolojisinin diğer stüdyo tabanlı pratiklere nasıl entegre edilebileceği ise bu teknolojinin dersin stüdyo saatleri içerisinde erişilebilir ve kullanılabilir hale getirilip onun diğer stüdyo tabanlı pratikler için ya da içerisinde kullanılıp kullanılmayacağı gözlemlenerek

sorgulanmıştır.

Stüdyo içi çalışma boyunca SG teknolojisi üç kez dersin jüri patiklerine entegre edilmeye çalışılmış olup, son denemede başarıya ulaşılmıştır. Her deneme, jüri oturumlarında kayıt altına alınan gözlemler ve kullanıcı gruplarıyla yapılan mülakatlarla irdelenmiştir. Mülakatlar öğrencilerle grup mülakatları şeklinde, eğitmen jüri üyeleri ile bire bir mülakatlar şeklinde gerçekleştirilmiştir. Davetli jüri üyeleri ile yüz yüze mülakat yapma imkânı bulunmadığı için onların görüşleri elektronik posta vasıtasıyla alınmıştır. Bu denemeler ve irdelemeler, öğrenci ve eğitmenlerin ihtiyaç ve talepleri doğrultusunda çözümler geliştirerek SG teknolojisinin endüstriyel tasarım eğitiminin jüri uygulamasına nasıl entegre edilebileceğini adım adım göstermektedir.

Öte yandan, SG teknolojisinin dersin stüdyo saatleri içerisinde erişilebilir ve kullanılabilir hale getirilmesine ek olarak donanım ve yazılımının nasıl kullanılacağına dair kısa bir eğitim verilmesinin, öğrenciler tarafından tasarım değerlendirme aracı olarak kullanılmasının önünü açtığı görülmüştür. Fakat, ne öğrenciler ne de eğitmenler, öğrencilerin ve eğitmenlerin birlikte yer aldığı diğer pratiklerde ve etkinliklerde SG kullanmayı talep etmemiş ve böyle bir girişimde bulunmamışlardır.

Stüdyo içi çalışmanın bulguları göz önünde bulundurularak, araştırmanın son adımında,

(i) SG teknolojisinin son jüri oturumunda (son denemede) kullanılması için önerilen yolun kullanılabilirlik düzeyi, Sistem Kullanılabilirlik Ölçeği (SUS) yardımıyla ölçülmüş,
(ii) Öğrenci ve eğitmenlerin proje sürecinde kullandıkları SG teknolojisine ve bu teknolojinin endüstriyel tasarım eğitiminde kullanımına ilişkin nihai değerlendirmeleri, hem öğrenciler ve eğitmenlerle yapılan mülakatlar, hem de Genişletilmiş Birleşik Teknoloji Kabulü ve Kullanımı Teorisi (UTAUT2) ve Net Destekçi Puanı (NPS) ölçeklerinden uyarlanan anket maddeleri yardımıyla ortaya çıkarılmış, ve
(iii) SG teknolojisinin öğrenci ve eğitmenlerin bir arada yer aldığı diğer pratiklerde ve etkinliklerde kullanılmamasının nedenleri öğrenci ve eğitmenlerle yapılan mülakatlar yardımıyla sorgulanmıştır.

SUS puanı 71,3 olarak hesaplanmıştır ve bu puan, endüstriyel tasarım eğitiminin jüri uygulamalarında SG teknolojisinin kullanımına yönelik son önerinin kullanılabilirliğinin yeterli olduğunu ancak geliştirilebileceğini göstermektedir.

Ayrıca, öğrenci ve eğitmenlerin, hem proje sürecinde kullandıkları SG teknolojisine dair, hem de SG teknolojinin endüstriyel tasarım eğitiminde kullanımına dair nihai değerlendirmeleri ortaya koymaktadır ki, SG teknolojisini çeşitli açılardan yararlı, kullanımını ise çeşitli derecelerde kolay bulmalarına rağmen zihinlerinde halen bazı çekinceler bulunmaktadır. Ancak bu sefer bu çekinceler,
(i) SG teknolojisinin sık veya sürekli kullanımı ile ilgili kolaylaştırıcı koşulların yeterince mevcut olmadığı düşüncesine, ve
(ii) Küçük ürünlerin tasarımlarını değerlendirmek için kullanılmasının çok yararlı olmayacağı düşüncesine dayanmaktadır.

Öte yandan, öğrenci ve eğitmenlerin birlikte yer aldığı diğer pratiklerde ve etkinliklerde SG teknolojisinin kullanılmamasının nedenlerinin
(i) Bu tür etkinlik ve uygulamalarda SG kullanımına dair henüz yeterli aşinalık ve hakimiyete sahip olunmamasıyla,
(ii) SG teknolojisini, bir tasarımın parçalarını değil de yalnızca bütününü bitmiş bir model üzerinden değerlendirmeye ve/veya sunmaya olanak tanıyan bir teknoloji olarak algılamakla, ve
(iii) SG kurulumunun ihtiyaç duyulduğu anda kullanıma hazır olmaması

ile ilgili olduğu görülmüştür.

Tüm bunlara ek olarak katılımcılar, endüstriyel tasarım eğitiminde SG teknolojisinin kullanımının sürdürülebilir olabilmesi için
(i) Stüdyo ortamında kalıcı/sabit bir kurulum ile hem öğrenciler hem de eğitmenler için kolay erişilebilir ve kullanılabilir olması,
(ii) Kullanımına en az bir eğitmen veya yöneticinin önderlik etmesi ve teknolojinin kullanımını yönetmesi, ve
(iii) Teknolojinin kurulum, öğrenme, çalıştırma ve bakım gereksinimleri gibi gereksinimlerinin en az bir teknik personel veya uzman veya operatör tarafından karşılanması

gerektiğini düşündüklerini dile getirmişlerdir.

Sonuç olarak, bu tez çalışması
(i) SG teknolojisini endüstriyel tasarım eğitiminin jüri uygulamasına entegre etmenin yollarından birini adım adım göstererek;
(ii) Endüstriyel tasarım eğitiminin diğer stüdyo tabanlı pratiklerine nasıl entegre edilebileceğinin ipuçlarını ortaya koyarak; ve

(iii) Endüstriyel tasarım öğrencilerinin ve eğitmenlerinin endüstriyel tasarım stüdyosu derslerinde SG teknolojisinin fiilen kullanılmasından önce ve sonra ilgili teknolojinin kullanımına yönelik olası tutumlarının neler olabileceğini ana hatlarıyla çizerek

ilgili literatüre katkı sunmaktadır.

Bu tez çalışması, SG teknolojisini bir endüstriyel tasarım stüdyosu dersinin gerçek koşulları altında kullanmaya çalışarak endüstriyel tasarım eğitimine entegre etmeye yönelik literatürdeki ilk girişimlerden biridir. Bu nedenle, sonuçlarının benzer çalışmalarla doğrulanması ve/veya iyileştirilmesi gerekmektedir. Ayrıca, çalışmanın ilgili kısmı yapılandırılmamış müdahale ile yürütülmüş olduğundan SG teknolojisinin endüstriyel tasarım eğitiminin jüri uygulaması haricindeki stüdyo tabanlı uygulamalarına nasıl entegre edilebileceği henüz yeterince açık değildir. Bu nedenle, bu konuda yapılandırılmış müdahalelerle yapılacak daha ileri çalışmalara da ihtiyaç olduğu belirtilmelidir.

1. INTRODUCTION

This chapter introduces the problem statement and the research question, the aim and the scope of the study, and presents an overview of the thesis structure.

1.1 Problem Statement and Research Question[1]

In 1981, the first personal computer (PC) of IBM and the first mass-produced portable computer (Osborne 1) were released. One year later, Commodore 64, which is a widely known PC even today, was released with an introductory price of $595 and became the greatest selling single computer of all times. In the same year, the first battery-powered laptop (GRiD) was introduced (Computer History Museum, 2020). On the other hand, in 1983, the AutoCAD version running on PCs was released by Autodesk with a price of $1000 (Weisberg, 2008). With these developments, computers have become economically accessible tools for designers. This commercial and economic availability of PCs with relevant software has paved the way for an accelerated penetration of computer technology into industrial design practice and caused remarkable changes in this field (Aldoy & Evans, 2011; Garner, 1999; Sener & Wormald, 2001). These major changes and their reflections on industrial design practice are chronologically summarized in Figure 1.1 mainly based on the information from the website of Computer History Museum (CHM).

According to this summary (see Figure 1.1), computer-aided drawing/design (CAD) software is the first computer technology that affected the industrial design practice in the 1980s. At the beginning of deployment of CAD software, competency degree in recording and manipulating 3-dimensional (3D) data was insufficient so that CAD technology was primarily used for 2-dimensional (2D) representations, such as technical drawing and drafting, in industrial design practice (Garner, 1999). However,

[1] Discussions in this part of the thesis are published in the article entitled "An overview of virtual reality within industrial design education". doi: 10.1108/JEDT-02-2020-0048

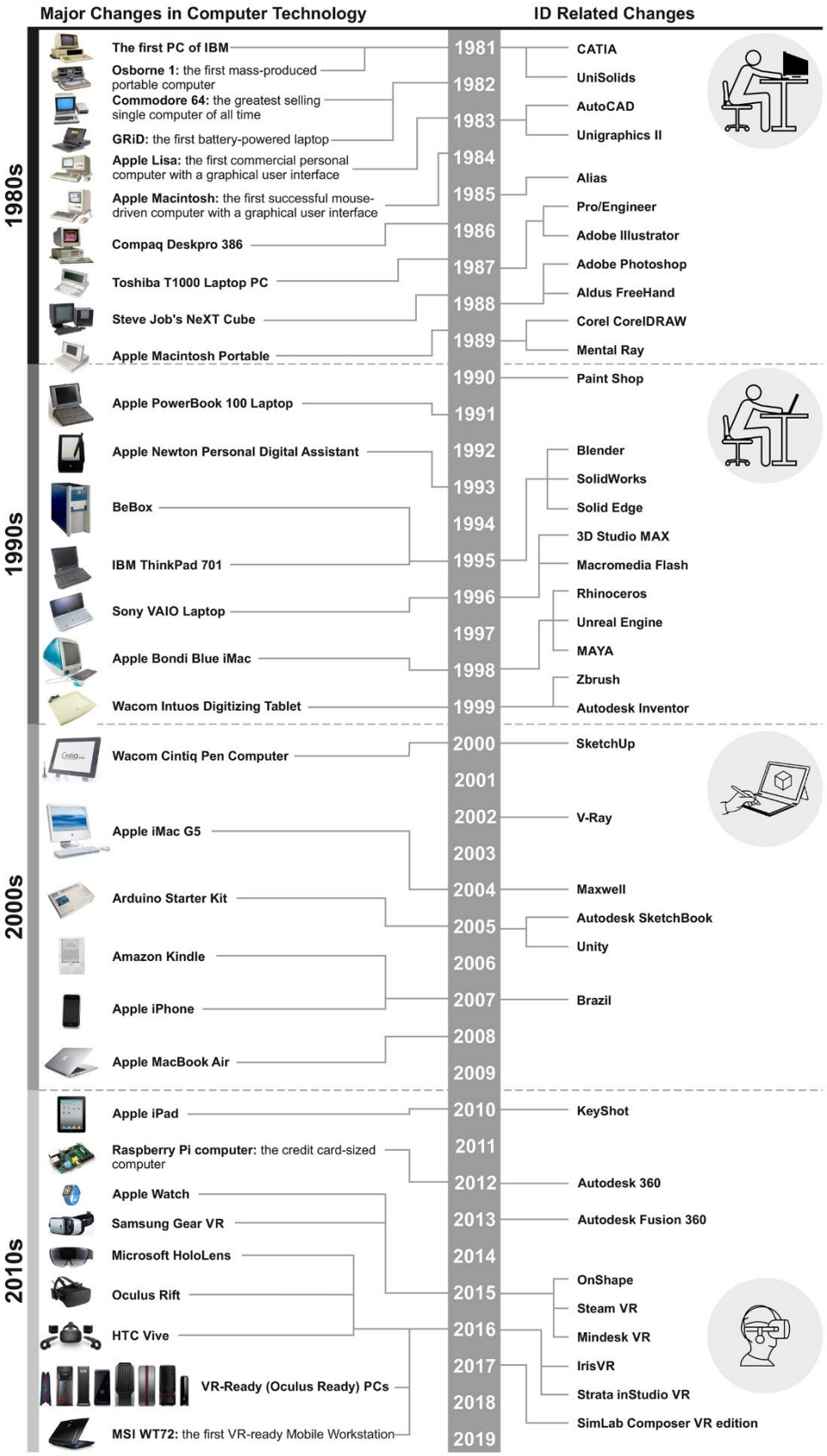


Figure 1.1 : Major changes in computer technology and their reflections on the representative tools of industrial design, taken from (Hamurcu et al., 2020, p. 1893).

this deficiency has been eliminated in a short time, and CAD software has become one of the most often used tools for creating 2D and/or 3D design representations. On the other hand, in the late 80s, the emergence of Photoshop – which is a raster-based software –, and Illustrator, CorelDraw, and Freehand – which are vector-based software – have increased computer's competence in producing sketch drawings, renderings and graphical representations. With these developments in the 80s, personal computers and laptops with relevant software have emerged as alternative ways for the conventional ways of representation i.e. drawing, rendering, and modelling.

In the 90s, pen-based interaction devices became commercially available for designers. Thus, by means of these devices called "digitizing tablets", which are used as computer peripheral, digital drawing and rendering with directly natural hand motions became possible for designers. With the developments in this computer technology, which offered a new human-computer interaction way different from the combination of keyboard and mouse, even computer screens became paper surfaces for designers, which are known as "pen computers". Thus, digitizing tablets and pen computers have taken their place among digital tools used by designers as other alternative ways for drawing and rendering by hand (Beyond, 2014).

On the other hand, computer technology also became a technology that can be run as embedded into or integrated with machining tools such as CNC (Computer Numerical Control) machining and rapid prototyping tools, in other words, 3D printers. In this way, these tools have offered alternatives to the conventional ways of model making and prototyping as well.

By the penetration of developing computer technology into industrial design practice, designers' major practices such as drawing, rendering, model making and prototyping, which had to be done by hand before, now, can be done within a computer environment or with the aid of computers. As a reflection of these developments on industrial design education, today, for the creation of 2D and/or 3D design representations, computers with CAD software, raster-based and vector-based software are used by students as the main alternative ways of hand-made drawing and rendering, whereas CNC machining tools and 3D printers are used as the major alternative ways for hand-made model making and manual machining (Figure 1.2).

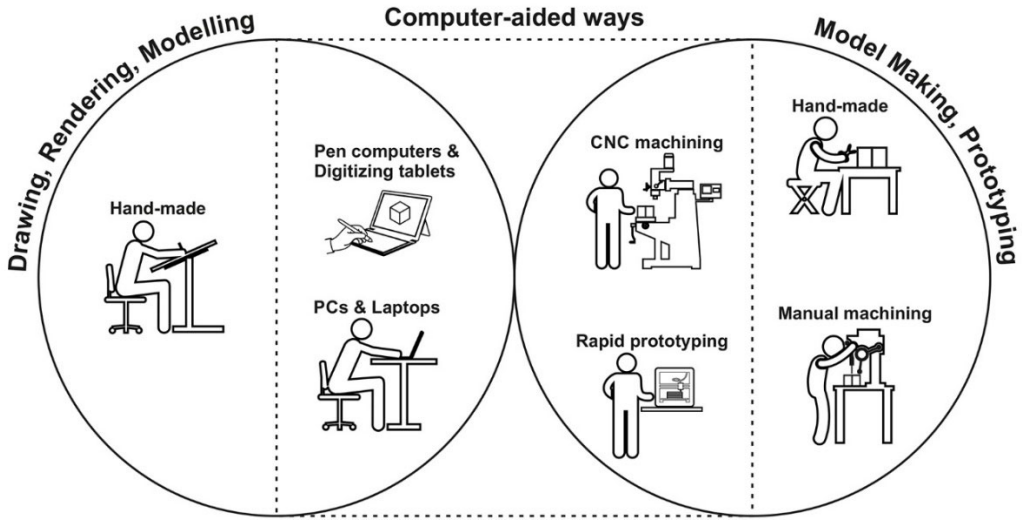


Figure 1.2 : A generic schematization of the production ways commonly used for creating design representation in industrial design education, taken from (Hamurcu et al., 2020, p. 1894).

Actually, these technologies just offered digital alternatives for creating design representations and had not brought such a remarkable innovation for the presentation of design ideas. Before these technologies, to create design representations, designers had two main options depending on hand work:

— to draw and render on a paper; and/or

— to make a physical model, or prototype

Yet, drawing and rendering on a paper is nothing more than an effort to show or explain 3D design ideas on a 2D plane, and making a physical model or prototype is to struggle with some difficulties such as material limitations. In other words, before computerization, the designer either was restricted with the 2D surface of the paper if s/he wanted to create her/his design representation by drawing and rendering, or had to manage the problems related to the materials if s/he wanted to make a physical 3D representation. Therefore, CAD technology allowed designers to create 3D design representations without any requirement of a physical material. Thus, in creating 3D representations, they have gotten rid of both the restrictions of 2D paper surfaces and the limitations of materials, and any other material-related problems. However, in order to present the representations created in computer environments, designers still have to print them on paper, display on a digital screen, or project on a screen. Papers, digital displays, and projection screens are 2D planes, and in this case, it cannot be said that, for those, who will evaluate by experiencing these representations, the

restrictions of the 2D plane were eliminated. This is also true in industrial design education. Students have to present their design representations, which they created on a paper or in a computer environment, through 2D planes unless they construct them with physical materials.

In brief, with the integration of computer technology into industrial design practice, alternative ways for students to create their 2D and 3D design representations emerged, but in terms of presenting them, the situation has not changed so much. (Figure 1.3).

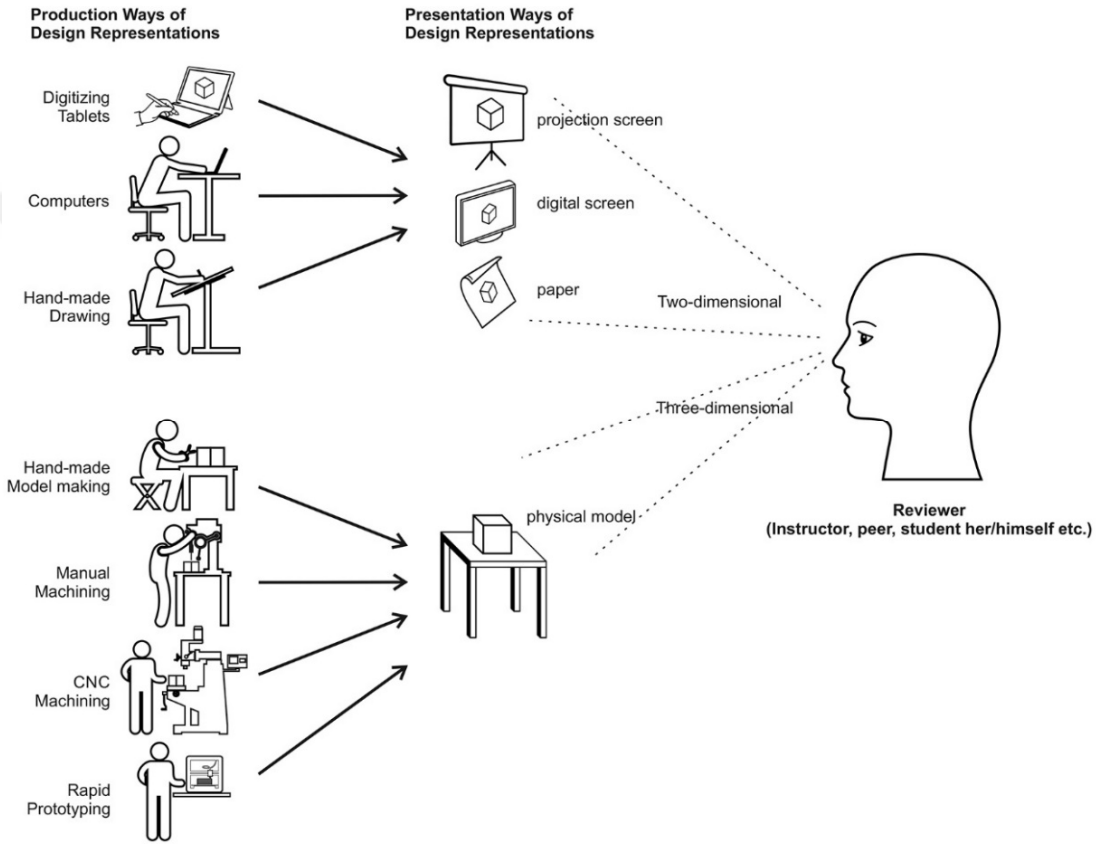


Figure 1.3 : Commonly used production and presentation ways of design representations by industrial design students, taken from (Hamurcu et al., 2020, p. 1895).

However, in 2016, immersive virtual reality (VR) environments in which viewers can interact with digital representations naturally and intuitively became economically available for designers by the release of VR headsets with related software such as HTC Vive and Oculus Rift. This was a new computer technology for designers not only offering another alternative way for creating design representations but also opening a completely new way for presenting, evaluating, and experiencing them. For this reason, it was quickly adopted by professional designers in many areas of industry such as automotive, furniture, and consumer durable. Barr & Juricic (1994) have

already stated that “the designer of the future will work in cyber-space, a world of virtual reality where laser beams paint the world view directly onto the designer’s retina”. So, it is not surprising. However, although computerization in industrial design studio course environments is described by Dorta et al. (2016) with the phrases “premature introduction” and “traumatic transition” due to the rapid adoption[2] of the other computer technologies developed before this immersive VR technology such as computer-aided drawing/design (CAD), digitizing tablets/pen computers, and 3D printers, this is not the case yet regarding the adoption of VR in industrial design education.

Notwithstanding, industrial design education is structured mainly based on a simulation of a professional design studio where instructors act as clients, and students are expected to behave as if they are designers (Andia, 2002; Laiserin, 2002; Lawson, 2005; Schön, 1985, 1987). Therefore, of course, it is affected by technological developments in the professional practices of industrial design. Also, according to the basic competency index of the National Association of Schools of Art and Design (NASAD) (2020), industrial design students “must acquire a working knowledge of technologies and equipment applicable to their area(s) of specialization” and they have to gain the “ability to use technologies and tools associated with multi-dimensional design representation, development, dissemination, and application”. As a result, it can be said that this newly emerged VR technology, as well, will eventually take its place among computer technologies used in the educational practice of industrial design. However, how this integration will be realized is not clear enough yet. For these reasons, the question below arises, and this thesis is guided and structured by this research question.

How can virtual reality technology be integrated into industrial design education?

1.2 Aim and Scope of the Study

Industrial design studio courses constitute the backbone of industrial design education. All mechanisms of learning and teaching industrial design are mainly based on studio-

[2] The word “adoption” in this thesis study is used by referring to “accepting or starting to use something new” which is the definition of “Cambridge Dictionary” (Cambridge Dictionary, 2020a).

based practices in these courses (Aytaç et al., 2008; Goldschmidt et al., 2010; Hough, 2013; Laiserin, 2002; Schadewitz & Zamenopoulos, 2009). In line with this, the word "integration" in the research question refers to the use of VR technology in and/or for these practices in a way that would not disrupt the flow of the course. Accordingly, within the framework of this study, the answer to this research question was researched by trying to incorporate the use of VR technology into these practices under real conditions in the setting of an industrial design studio course. In other words, this research is an action research that seeks how VR technology can be integrated into industrial design education by trying to use it in an industrial design studio course.

On the other hand, there are two main systems for industrial design studio courses called *horizontal* and *vertical*. The horizontal studio system is based on a projection that the students who enter the department together will take all studio courses together from first to fourth-year classes, and graduate together. However, in the vertical system, students get clustered as semester groups when they enter the department, and groups for studio courses are composed of students selected from different semester groups each semester (Hough, 2013). This study was conducted in the ITU Department of Industrial Design, which implements the horizontal studio system.

Nevertheless, the integration of a new technology or a new product depends on whether users accept it to use or not (Louho et al., 2006). Users' acceptability of that technology or product depends on their willingness to use it (Dillon, 2001). According to Davis (1989), if people believe that technology will help them do their work better and easier, they will tend to use that technology. He states that "perceived usefulness", and "perceived ease of use" are the key determinants of an individual's intention to use. For these reasons, this research is built and conducted mainly based on the attitudinal data gathered from industrial design students and instructors on the usefulness and ease of use (usability) of VR technology within industrial design education. And, it is supported by behavioral data where relevant.

In brief, this research aims;

— To find out ways for integrating VR technology into the studio-based practices of industrial design education.

And, the refined scope of the study (Figure 1.4) is;

— Use of VR technology with headsets/glasses,

— For/in studio-based practices,

— In industrial design studio courses,

— By stakeholders (instructors, students, invited jury members, etc.).

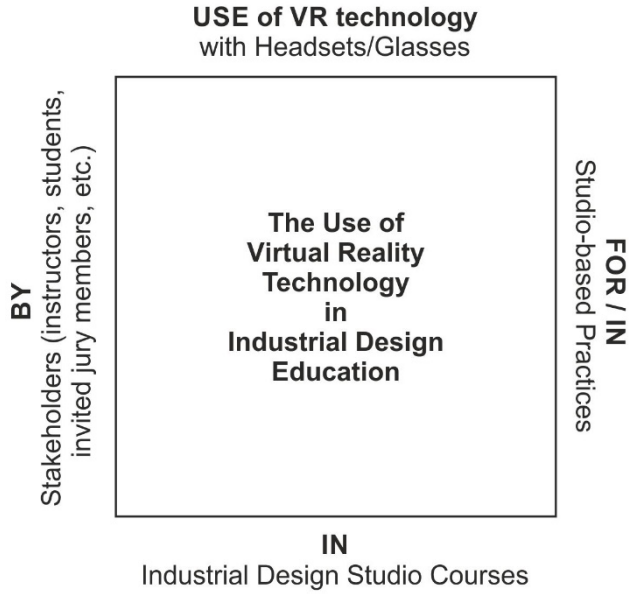


Figure 1.4 : Scope of the study.

1.3 Thesis Structure

This thesis consists of six chapters:

First chapter (1. INTRODUCTION) introduces the research question with the problem statement of the study, the aim and the scope of the study. Also, in this chapter, the structure of the thesis is presented.

The next chapter (2. LITERATURE REVIEW) presents relevant literature-based information on the fields of *"industrial design processes in practice and education"* and *"virtual reality"* that are two main domains on which the study is built, and the possible types of the use of VR technology in design processes.

The following chapter (3. THEORETICAL FRAMEWORK) presents theories and models on which this thesis study is based.

The next chapter (4. METHODOLOGY) presents the methodological framework of the study along with the research design and approach. Also, the validity, reliability, and generalizability of the study are discussed in this chapter.

In the following chapter (5. PROCEDURES, METHODS AND FINDINGS OF THE RESEARCH), how the research was conducted, and the findings reached throughout and at the end of the research process are delivered.

Finally, in the concluding chapter (6. CONCLUSIONS), general overview and final remarks on the study are presented. Besides, the conclusions of the study, the contributions of the study, the limitations of the study, and the recommendations for further studies are delivered.

The thesis structure is also presented schematically in Figure 1.5.

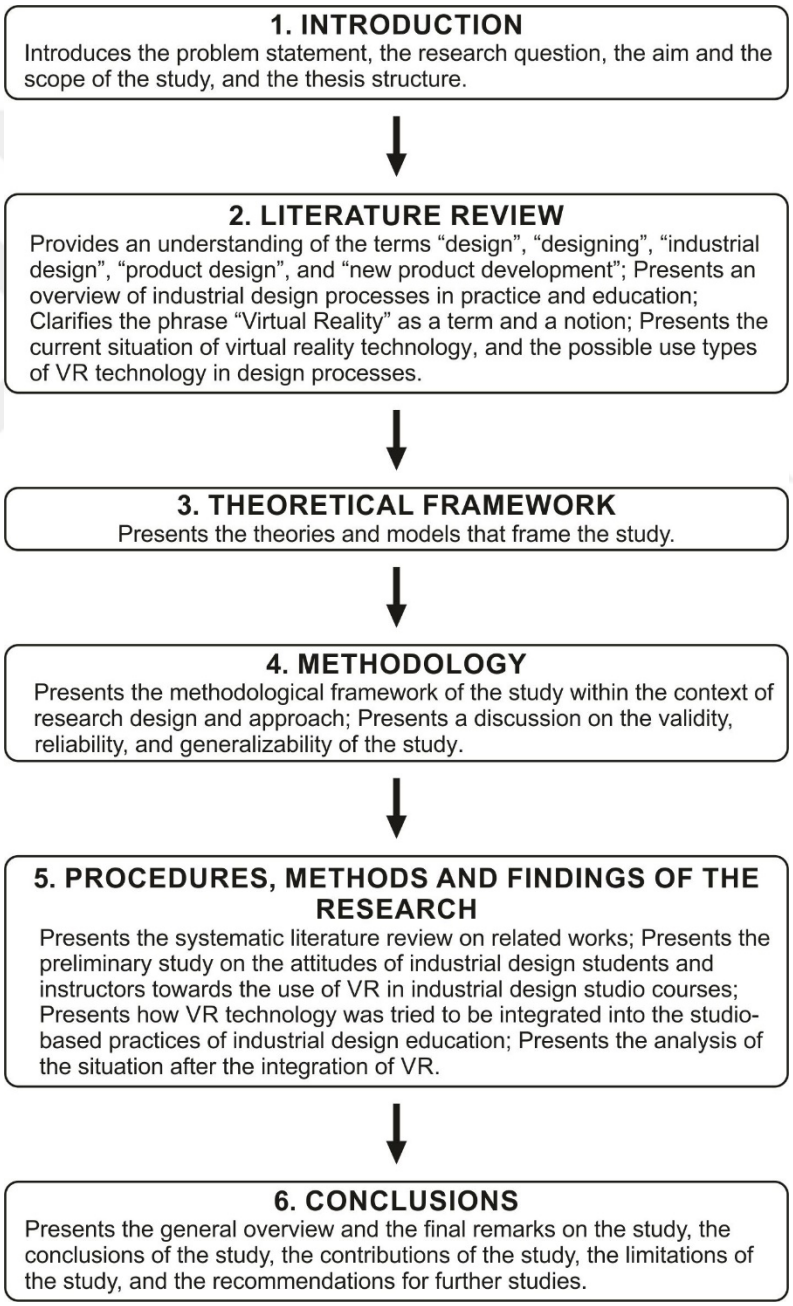


Figure 1.5 : Structure of the thesis.

2. LITERATURE REVIEW

This chapter, first of all, provides an understanding of the practice of industrial design over the notions “design”, “designing”, “design representation”, “industrial design”, “product design”, and “new product development”. Secondly, an overview of industrial design education and the core activities associated with it are presented. Following, based on the literature regarding VR technology, the term and the notion of “Virtual Reality” used in this thesis are clarified, and an analysis of existing VR systems is presented. Finally, the possible types of use for VR technology in professional and educational processes of industrial design are questioned.

2.1 Industrial Design Processes in Practice and Education

2.1.1 Definitions of design and industrial design

Defining the term “design” is not so easy. Because, the term “design” has more than one meaning and its meaning depends on the context in which it is used (Walker, 1989). Another difficulty in defining the word “design” is that it can be used both as a noun and as a verb. John Heskett (2002) gives emphasis on this situation by saying “Design is to design a design to produce a design” (p. 5). This can also be “why designers find it so difficult to explain what they do” (Lawson, 2005, p. 285). Nevertheless, it is possible to *describe* “design” based on the definitions in the literature.

According to “Online Etymology Dictionary”, the word “design” comes from the Latin verb “designare” which means to mark out, point out, devise, choose, designate, appoint (Online Etymology Dictionary, 2020). On the other hand, Jonathan Hill (2003) claims that “design” originates from the Italian word “disegno” whose meaning is “drawing”. He bases his argument on Giorgio Vasari who used the word “disegno” to define some design activities such as painting, sculpting and architecture (as cited in Bürdek, 2005). According to Hill (2003), “disegno” refers “a direct link between an idea and a thing” (p. 165). Likewise, Vasari (1960) states that “design is not other than

a visible expression and declaration of our inner conception" (p. 205). Other descriptions of "design" in the literature are presented chronologically in Table 2.1.

Table 2.1 : Some other descriptions of "design" and "designing" in the literature.

Reference	Description
Archer (1965)	"… the act of arriving at a solution by strict calculation is not regarded as designing… design involves a prescription or model, the intention of embodiment as hardware and the presence of a creative step" (p. 4).
Dilnot (1982)	"'design' as a term 'which is a noun and a verb, and also one which denotes a form of representation, an activity, a practice, a product, etc.," (p. 140).
Finkelstein & Finkelstein (1983)	"Design is the creative process which starts from a requirement and defines a contrivance or system and the methods of its [realization] or implementation, so as to satisfy the requirement" (p. 213).
Krippendorff & Butter (1984)	"Design is the conscious creation of forms to serve human needs" (p. 4).
Roy & Potter (1990)	"What is common to all these types of design is that they involve creating concepts, plans and instructions, usually in response to a brief provided by a firm or client, that enable a two- or three-dimensional object that did not exist previously to be made" (p. 322).
Jones (1992)	"the initiation of change in man-made things" (p. 6)
Simon (1996)	"changing existing situations into preferred ones" (p. 111)
Lawrence (as cited in: Buchanan, 2000)	"Design is the term we use to describe both the process and the result of giving tangible form to human ideas" (Buchanan, 2000, p. 4)
Dumas (2002)	"It is the process of turning ideas into material things" (p. 1)
Nelson & Stolterman (2003)	"Design is the ability to imagine *that-which-does-not-yet-exist*, to make it appear in concrete form as a new, purposeful addition to the real world" (p. 10).
Hooker (2004)	"Design is a passage from a functional description to a physical description of an artifact" (p. 75).
Goldschmidt (2004)	"Design is to represent, and in no case is there design without representation" (p. 203).
Bürdek (2005)	"a plan or scheme devised by a person for something that is to be realized" (p. 13).
Welch (2007)	"Designing is seen to be a conscious process through which a designer transforms ideas into a tangible outcome" (p. 23).
Van Boeijen & Daalhuizen (2010)	"to conceive the idea for some artifact or system and to express that idea in an embodiable form" (Part 1 | Product Design in Delft – 1.1).

On the other hand, "industrial design" is defined by ETMK (Industrial Designers' Society of Turkey) (n.d.) as "the profession which conceptually develops products manufactured by industry for the end user according to criteria such as functionality, taste of the target group and user needs, and which projects them as new products suitable for production". "Industrial design" is also described by the Industrial Designers Society of America (IDSA, n.d.), as "the professional practice of designing

products, devices, objects, and services used by millions of people around the world every day". According to the World Design Organization (WDO, 2015), industrial design is "a trans-disciplinary profession that harnesses creativity to resolve problems and co-create solutions with the intent of making a product, system, service, experience or a business, better".

Another issue that needs to be clarified for this study is the confusing use of terms "product design" and "industrial design". According to Slack (2006), "product design is a generic term for the creation of an object that originates from design ideas – in the form of drawings, sketches, prototypes, or models – through a process of design that can extend into the object's production, logistics, and marketing" (p. 6) and for Eppinger et al. (1990), Cooper & Press (1995) and Slappendel (1996), industrial design is a part of product design. However, some scholars such as Unver (2006), Pei (2009) and Aldoy (2011) reported that these two terms can be frequently used interchangeably in most cases. To escape confusion, the terms "industrial design" and "product design" will not be used as interchangeable throughout this thesis, and the aforementioned definitions of both terms will be accepted and used instead.

2.1.2 Industrial design process

In the literature, there is a wide variety of descriptive and prescriptive model proposals to depict design process which can be basically defined as an iterative and creative process. Descriptive models illustrate simplistically the activity sequences that usually occur in designing, whereas prescriptive ones try to define a better or more appropriate pattern of these activities (Cross, 2000). Some of the frequently cited models in the literature are as follows.

Jones's model: It is one of the most simplistic model proposals. It consists of just three stages that involve very basic and key activities: "Analysis", "Synthesis" and "Evaluation" (Jones, 1992) (Figure 2.1 a). In this model, "Analysis" phase is the phase that the problem is divided into its components and the requirements of the product are examined. In the "Synthesis" phase, solutions are generated and developed for each pre-defined problem. And, finally, in the "Evaluation" phase, developed solutions are evaluated and one of them is selected as best to fulfill the requirements (Aldoy, 2011; Jones, 1992).

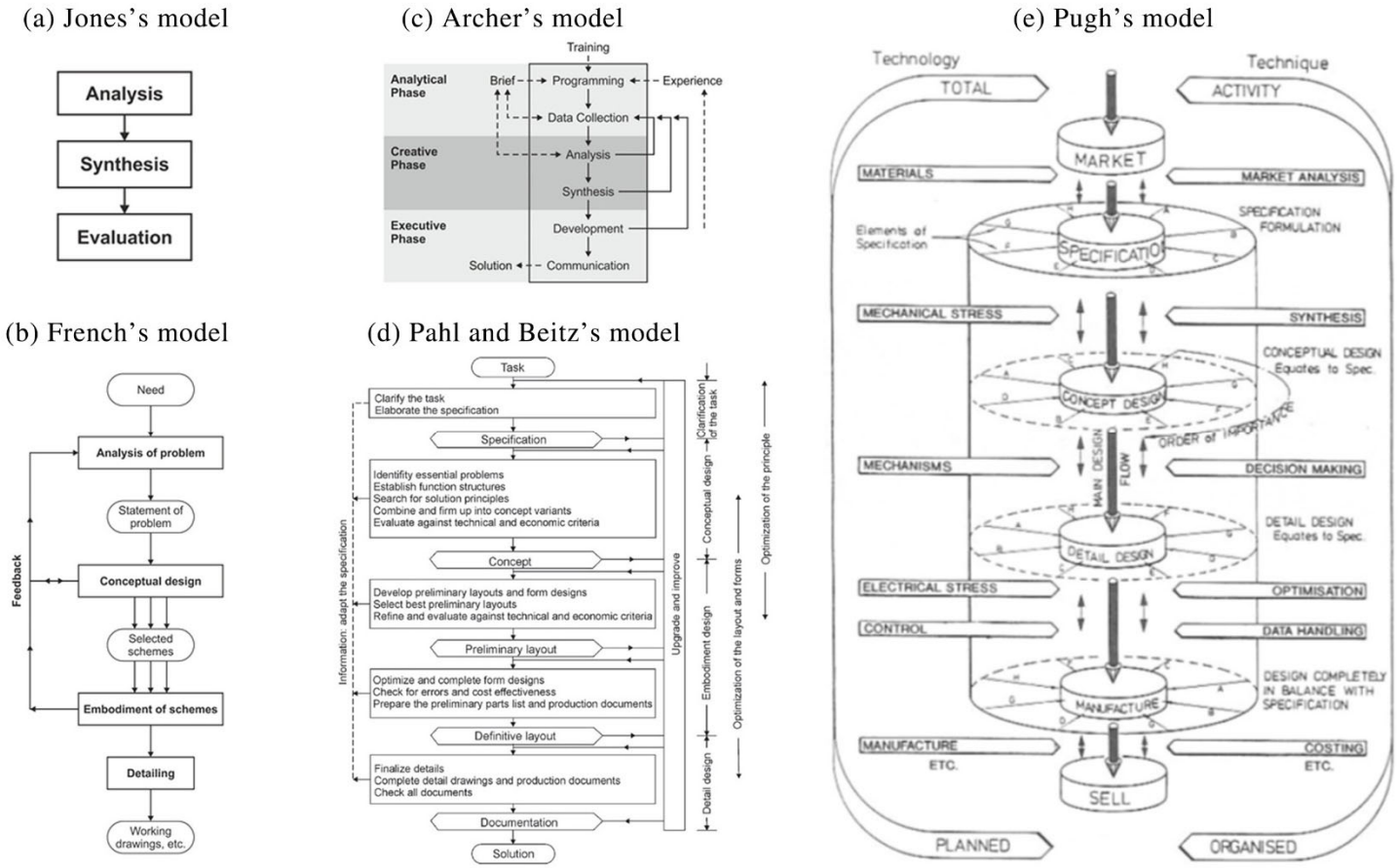


Figure 2.1 : Some of the frequently cited models in the literature: (a) Jones's model (Jones, 1992), (b) French's model (French, 1985), (c) Archer's model (L. B. Archer, 1965), (d) Pahl and Beitz's model (Cross, 2000, p. 37), (e) Pugh's model (Pugh, 1991, p. 11).

French's model: This model consists of four main stages ("Analysis of problem", "Conceptual design", "Embodiment of schemes" and "Detailing") and four accompanying "statement stages" ("Need", "Statement of problem", "Selected schemes" and "Working drawings, etc.") (French, 1985) (Figure 2.1 b). "Statement stages" refers to stages whose output is a statement. The process starts with observing market needs and analyzing detected needs to establish the problem statement. The requirements that must be fulfilled by the product are defined in addition to the problem statement. In the conceptual design stage, several concepts are come up with as schemes, and then, more realistic representations of them are produced for evaluation and comparison. One or more concepts are selected and embodied. The process is ended up with adding details and manufacturing drawings, etc. (Wynn, 2007) However, one of the major differences of this model is that, by adding feedback loops, it highlights that design process is an iterative process (Cross, 2000).

Archer's model: It is very similar to Jones's model in terms of handling the process in three phases: "Analytical" phase, "Creative" phase and "Executive" phase. However, each phase in this model has two stages. Thus, the design process is divided into six stages: Programming, Data collection, Analysis, Synthesis, Development and Communication (L. B. Archer, 1965) (Figure 2.1 c). The activities in these stages are briefly and respectively described as follows: programming for establishing problems; collecting and storing data and information; analyzing sub-problems; synthesizing by sketching design proposals; developing them by preparing and executing prototypes; and communicating and documenting for production. Another difference of this model is that external factors such as client contributions with "brief" and designer's training and experience are covered as well (Aldoy, 2011; Pei, 2009).

Pahl and Beitz's model: It is a comprehensive model that has four main phases – "Clarification of the task", "Conceptual design", "Embodiment design" and "Detail design" –, and their sub-stages which can be considered as working steps (Pahl & Beitz, 1996) (Figure 2.1 d). This model can also be evaluated as a guideline that highlights the essential things to be taken into consideration and delivers the steps to schedule design process (Wynn, 2007).

Pugh's model: This model named as "total design" by Pugh (1991) combines prescriptive engineering models which consider design process as a linear process and descriptive design models that describe cognitive processes in a spiral and cyclical

way (Pei, 2009). In this model, there is a central design core made up of defining market needs, formulating design specifications, generating concepts, detailing design, manufacturing and selling the product (Figure 2.1 e). Technological knowledge and the activities such as "market analysis", "synthesis", "decision-making", "optimization", "data handling" and "costing" are evaluated as external factors or activities providing input for design process (Aldoy, 2011; Pugh, 1991).

According to Pei (2009), all of the design process models in the literature can be classified into five distinct types as shown in Figure 2.6, and the models mentioned above as examples of widely-known design process models are also examples of these types.

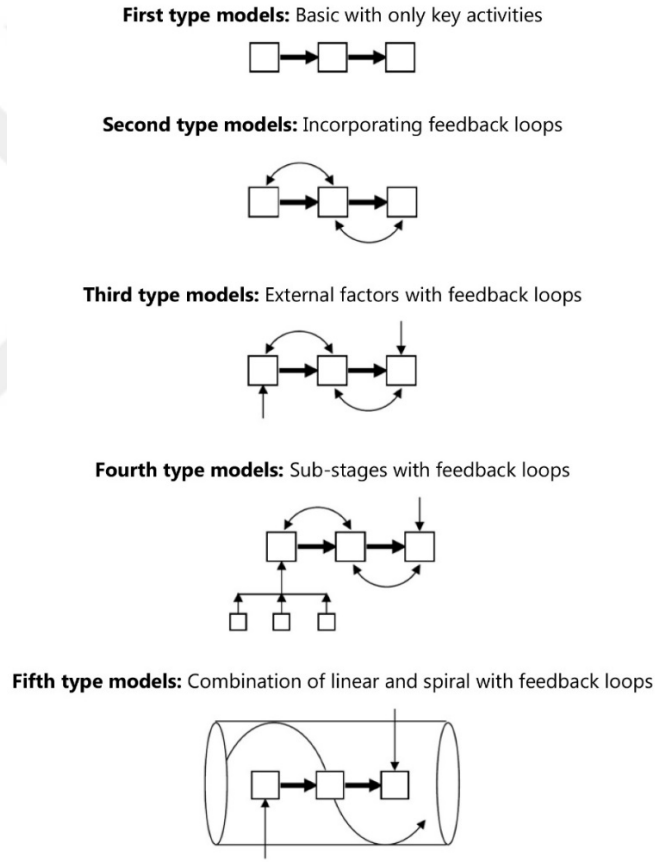


Figure 2.2 : Types of design process models, taken from (Pei, 2009, p. 26).

Other design process models in the literature are presented below with the comparison table of Howard et al. (2008) (Table 2.2) that includes those mentioned above as well.

On the other hand, design process, of course, is a creative process at the same time. Therefore, there are design process models in the literature which treat design process as a creative process. These models are also presented in Table A.1 of Appendix A. However, this research does not focus on creativity processes.

Table 2.2 : Design process models, taken from (Howard et al., 2008, p. 163).

Models	Establishing a need phase	Analysis of task phase	Conceptual design phase	Embodiment design phase	Detailed design phase	Implementation phase
Booz, Allen, & Hamilton (1968)	X	New product strategy development	Idea generation; Screening & evaluation	Business analysis; Development; Testing		Commercialization
Archer (1968)	X	Programming; Data collection	Analysis; Synthesis	Development	Communication	X
Svensson (1974)	Need	X	Concepts	Verification; Decisions	X	Manufacture
Wilson (1980)	Societal need	Recognize & formalize; FR's & constraints	Ideate and create	Analyze and/or test	Product, prototype, process	X
Urban & Hauser (1980)	Opportunity identification	Design		Testing		Introduction (launch); Life cycle management
VDI-2222 (1982)	X	Planning	Conceptual design	Embodiment design	Detail design	X
Hubka (1982)	X	X	Conceptual design	Lay-out design	Detail design	X
Crawford (1984)	X	Strategic planning	Concept generation	Pre-technical evaluation	Technical development	Commercialization
Pahl & Beitz (1984)	X	Clarification of task	Conceptual design	Embodiment design	Detail design	X
French (1985)	Need	Analysis of problem	Conceptual design	Embodiment of schemes	Detailing	X
Ray (1985)	Recognize problem	Exploration of problem; Define problem	Search for alternative proposals	Predict outcome; Test for feasible alternatives	Judge feasible alternatives; Specify solution	Implement
Cooper (1986)	Ideation	Preliminary investigation	Detailed investigation	Development; Testing & Validation	X	Full production & market launch
Andreasen & Hein (1987)	Recognition of need	Investigation of need	Product principle	Product design	Production preparation	Execution
Pugh (1991)	Market	Specification	Concept design		Detail design	Manufacture; Sell
Hales (1993)	Idea, need, proposal, brief	Task clarification	Conceptual design	Embodiment design	Detail design	X
Baxter (1995)	Assess innovation opportunity	Possible products	Possible concepts	Possible embodiments	Possible details	New product
Ulrich & Eppinger (1995)	X	Strategic planning	Concept development	System-level design	Detail design	Testing & refinement; Production ramp-up

Table 2.2 (continued) : Design process models, taken from (Howard et al., 2008, p. 163).

Models	Establishing a need phase		Analysis of task phase		Conceptual design phase		Embodiment design phase		Detailed design phase		Implementation phase	
Ullman (1997)	Identify needs	Plan for the design process	Develop engineering specifications		Develop concept		Develop product				X	
[BSI (1997)]	Concept		Feasibility		Implementation (or realisation)						Termination	
Black (1999)	Brief / concept		Review of 'state of the art'		Synthesis	Inspiration	Experimentation	Analysis / reflect	Synthesis	Decisions to constraints	Output	X
Cross (2000)	X		Exploration		Generation		Evaluation		Communication		X	
Design Council (2005)	Discover		Define		Develop			Deliver			X	

2.1.3 Industrial design within new product development

Otto & Wood (2001) and Ulrich & Eppinger (2003) describe the term "product development" as a set of activities employed for adding a new product to the market, which begins with establishing a market need and ends with production, sale, and delivery of a product. According to this description, design process models which end with "manufacturing", "launching" or "selling", that are presented in Table 2.2, actually depict the process of (new) product development. Moreover, Ulrich & Eppinger (2003) state that industrial design process is a sub-process of new product development (NPD) process (Figure 2.3).

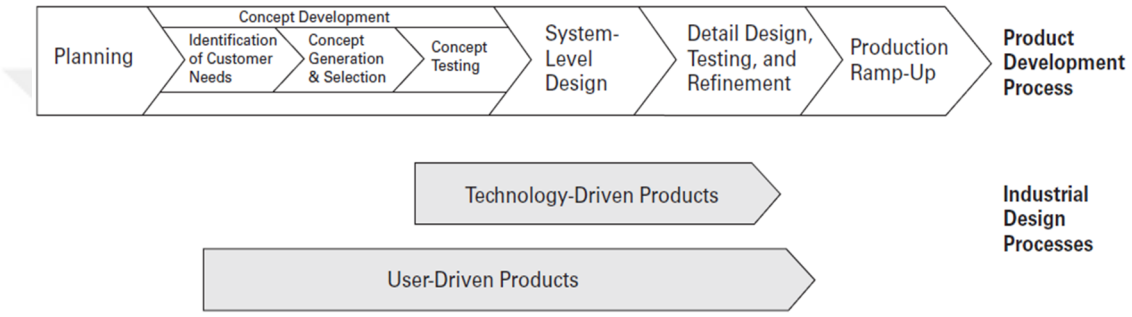


Figure 2.3 : Industrial design process within the new product development process, taken from (Ulrich & Eppinger, 2003, p. 202).

On the other hand, industrial design process is not a process that is conducted separately from new product development process (Ulrich & Eppinger, 2003). During the entire process of new product development, industrial designers collaborate with the other actors of that process such as engineers, manufacturers and marketing specialists (Hertenstein et al., 2005; Lofthouse, 2004; Ulrich & Eppinger, 2003). According to Hertenstein et al. (2005) and Gemser & Leenders (2001), industrial design process in new product development process is also a process that makes an essential contribution to the success of the product by coming up with solutions that meets the user needs, establishing the product's ergonomics and aesthetics, and conceives the product identity (Aldoy, 2011).

2.1.4 Design representations within industrial design practice

According to Chapman & Peace (1988), before modern industrial societies, there were times when the designer and the manufacturer were the same person (Figure 2.4). In those times, there was no need for those designer-manufacturer people to show their

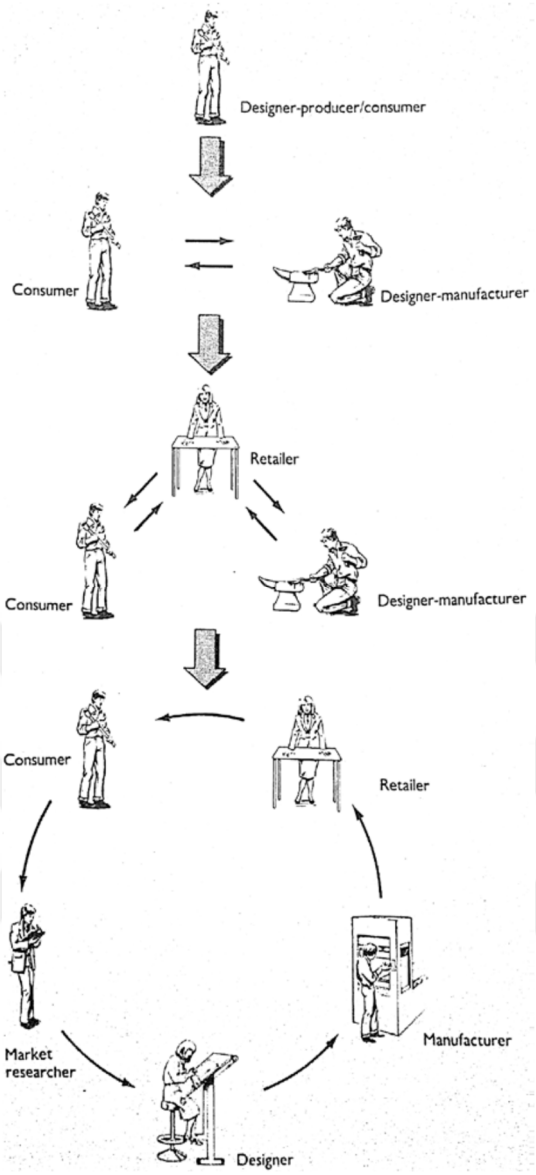


Figure 2.4 : Evolution of the product cycle, taken from (Chapman & Peace, 1988).

design ideas about the product to be manufactured to anyone else before the realization of the product. However, with the emergence of industrialization in mass production, the person responsible for design and the person responsible for production were categorically separated from each other. By this change, industrial design has emerged as a profession that works as a part of mass production and retailing cycle. Thus, sharing and criticizing design ideas with other actors of this cycle such as marketers and manufacturers before production has become a necessity for designers rather than an option. For such an assessment to be done, design ideas regarding how the product will look like, how it will work, etc. have to be externalized by visualizing and/or embodying. This is by definition a representation of what is intended before it is realized (Hamurcu et al., 2020). Actually, representation is a general term, and it can

be described as an object or thing that stands for anything else (Kaplan & Kaplan, 1982; Palmer, 1987; Pei, 2009). However, design representations can be described more specifically as physical or digital artifacts that reproduce, especially visually, features of a product being designed (Johnson, 1998; Pei, 2009). There are various types of them. Visual design representations are mainly categorized as 2D and 3D representations, and Pei et al. (2011) classifies 2D ones under the titles "sketches" and "drawings" whereas 3D ones under the titles "models" and "prototypes". Their classification of visual design representations is presented in Table 2.3. The details of these representations in this table are presented in Table A.2 and Table A.3 of Appendix A.

Table 2.3 : Classification of visual design representations, adapted from (Pei et al., 2011, p. 68).

2D Visual Design Representations		**3D Visual Design Representations**		
Sketches	**Drawings**	**Models**	**Prototypes**	
Idea Sketch	Concept Drawings	3D Sketch Model	Appearance Prototype	**Industrial Design**
Study Sketch	Presentation Drawing	Design Development Model	Alpha Prototype	
Referential Sketch	Scenario & Storyboard	Appearance Model	Beta Prototype	
Memory Sketch	Diagram	Functional Concept Model	Pre-Production Prototype	
Coded Sketch	Single-View Drawing	Concept of Operation Model	Experimental Prototype	**Engineering Design**
Information Sketch	Multi-View Drawing	Production Concept Model	System Prototype	
Renderings	General Arrangement Drawing	Assembly Concept Model	Final Hardware Prototype	
Inspiration Sketch	Technical Drawing	Service Concept Model	Tooling Prototype	
Prescriptive Sketch	Technical Illustration		Off-Tool Prototype	

On the other hand, design representations, whether 2D or 3D, are not only used for sharing and criticizing design ideas but also, they are used for many different purposes within industrial design practice. For example, according to Goldschmidt (2003) design representation is the extension of imagery, in other words, the externalization of design ideas in mind. This externalization enables designers to understand and to interpret the situation better, to think and to reason about situations that do not yet exist or cannot be experienced directly. In this way, design representations decrease the cognitive load in mental processing (Koutamanis, 1993; Römer et al., 2001; Schweikardt & Gross, 2000; Suwa & Tversky, 1997). Also, designers can see things

differently, and produce new insights and new ideas by making different readings on representations (Goldschmidt, 1991; Schön & Wiggins, 1992). Additionally, by means of design representations produced at different stages of the design process, the ideas and the interpretations generated during the process, and results or conclusions achieved can be followed easily. This assists the designer to organize his/her ongoing work (Do et al., 2000; Greeno & Hall, 1997; Visser, 2006). Moreover, sometimes, a design may contain lots of technical details, and detecting mistakes may not be so easy. In similar cases, design representations enable designers to examine their designs and recognize possible mistakes before manufacturing (Garner, 2004). Above all, design representations are "the designer's principal means of thinking" alongside their being a convenient way for solving design problems (Herbert, 1993). These and other functions of design representations within industrial design practice mentioned in the literature are summarized by Pei (2009) in terms of "personal", "social", "technical", and "aesthetic" aspects as in Table 2.4.

Table 2.4 : Uses of visual design representations, taken from (Pei, 2009, p. 137).

Aspect	Uses
Personal	— Makes it easier to convey information difficult to express in words — Acts as cognitive artefacts that suggest new meanings — To envision the design before manufacture — As a persuasive tool to sell the idea to management or marketing — To record thoughts — Serves to generate further ideas — To obtain information from a potential end-user or the client — Serves as a communication medium for ideas to be expressed — Relieves the cognitive load from memory — Structures information and represent data graphically — Allows the developer to focus on details or to look at the product as a whole — Does not require huge commitments in terms of time and cost
Social	— Stimulate dialogues among the group to achieve better design — Allows members to compare options easily — Shows stakeholders what one is thinking, enabling participation — Supports creative group activities — Helps to coordinate work within the group — Serves as a communication medium for ideas to be expressed — Integrates the perspectives of different functions — Allows stakeholders to obtain important design knowledge
Technical	— Allows the checking of final changes and detect last minute errors — Incorporate technical details made available for engineering designers — Shows the relationship of parts in terms of assembly and manufacture — Highlights technical or functional aspects behind the idea
Aesthetic	— Makes it easier for a complex design to be visualized — Allows greater control in the relationships of parts — To visually assess whether current idea meets the project objectives — Explains a series of actions e.g., step-by-step illustrations — Enhances awareness of visual details such as shape, texture and color — Allows the developer to test aspects such as size, proportion and color — Shows various viewpoints for a better understanding of shape and connections

2.1.5 Industrial design education

Industrial design education is a studio-based design education whose origins, in terms of framework and processes, were mainly founded in the "atelier" form by French École des Beaux Arts in the 1800s, and in the "workshop" tradition by Bauhaus in the 1900s (Broadfoot & Bennett, 2003; Goldschmidt et al., 2010; Kwan, 2010; Laiserin, 2002; Schadewitz & Zamenopoulos, 2009). Therefore, it can be seen that the words "studio", "atelier" and "workshop" are used interchangeably referring to: the course name in the curriculum; the physical place where that course is carried out; and the pedagogical system of the course (Broadfoot & Bennett, 2003; Hough, 2013; Shao et al., 2007).

During the industrial design studio courses, workflows and methods used by professional design studios to conduct design project processes are attempted to be followed by students and instructors. In other words, industrial design studio courses are theatric simulations of professional design studios. In the setting of the course, students try to behave as if they are professional designers whereas instructors act towards them as if they are clients or employers (Andia, 2002; Laiserin, 2002; Lawson, 2005; Schön, 1985, 1987).

An ordinary industrial design project process in the course involves generic stages such as: (i) the introduction of the design brief; (ii) establishment of the problem or user need; (iii) concept and/or idea generation; (iv) development of the design; and (v) finalization of the project by detailing design (Andia, 2002; Kvan, 2001; Kwan, 2010). With the introduction of the design brief, the individual, or the grouped design project process begins for students. During the project process, students are anticipated to work both in and outside the studio (hours) by reviewing the literature and undertaking research especially getting in touch with targeted users. All project process is conducted under the supervision of instructors, and from the beginning to the end, students are expected to present their processes periodically, and to get feedback from instructors via these presentations (Hough, 2013; Kvan, 2001; Uluoğlu, 2000).

2.1.5.1 Main studio-based practices of industrial design education: studio critiques

Schön (1985, 1987) describes the cognitive process of designers in the act of designing with the notions of "reflection-in-action" and "reflection-on-action". According to his

ideation, in the designing process, each action of the designer generates an effect in the situation, and this effect also gives feedback for the designer to verify, evaluate, change or reshape his/her approach to the situation, and go on. “Reflection-in-action” refers to this cycle which is described as a conversation between the designer and the situation by Schön (1987). On the other hand, “reflection-on-action” refers to the designer’s reflection on his/her finished action, and involves the reconstruction of the experience by recalling it (Ferreira, 2017; Schön, 1987). The design project process in industrial design education is a process through which instructors get involved in these “reflection-in-action” and “reflection-on-action” cycles of students. By means of studio critiques, instructors and students reflect together. Studio critiques in which these reflective interactions and communications between students and instructors occur can be performed in several formal and informal ways. Well-known types of informal ones are “desk-critiques”, and “pin-up”, also known as “wall critiques”. “Preliminary juries” and “final juries” are the formal ones. “Desk-critiques” are the criticizing sessions that an instructor and a student talk about the student’s project by coming together around a desk. Other instructors and students can contribute to these critiques with their comments. In “pin-up” or “wall critiques”, students present their projects with their sheets and/or other presentation materials in front of a board, or a wall, to the rest of the class, and get feedback from them. In brief, in an ordinary critique session, whereas students present and explain the current state of their project processes via their design representations, instructors try to understand and evaluate their projects and progress by listening to their explanations and examining these representations to help and guide them (Goldschmidt, 2002; Goldschmidt et al., 2010; Hough, 2013; Karadoğaner, 2020; Schön, 1985).

Preliminary and final juries are very similar to “pin-up” or “wall critiques”. The major difference of juries from other studio critiques is that students present their projects and processes to a jury, which generally consists of instructors, not only for evaluation but also for grading. Sometimes, professionals that are not resident actors of the studio course such as other instructors, design professionals, and firm managers can get involved in these juries as invited jury members (Andia, 2002; Hough, 2013; Kvan, 2001; Uluoğlu, 2000). Juries are not only for criticism and assessment means of industrial design education but also a rehearsal of professional life for students (Anthony, 1991; Ilgaz, 2009; Peterson, 1979; H. Webster, 2006, 2007). Another

difference of juries from pin-up, or wall critiques, is that they are carried out as a ritual with predefined sequential phases. According to Roberts (2004), these ritualistic jury sessions have eight successive phases as depicted in Table 2.5.

Table 2.5 : Eight phases of the design jury session by Roberts (2004), prepared based on (Ilgaz, 2009).

Phase	Description
1	*Preparation of presentation materials e.g. hanging the project sheets on a wall or a board, getting projector ready to use, etc.* Meanwhile, jury members and the audience can get a general opinion about the project if this preparation occurs in front of them.
2	*Giving background information on the project.* While the audience is getting informed by the student(s) about the project background, jury members focus on this oral presentation and displayed visuals.
3	*Describing the designed product.* Referring to representations of the designed product such as drawings, renderings, mock-ups, and prototypes, design details and decisions behind are explained by the student(s). In the meantime, taking the relationship between the oral presentation of the student(s) and the context into consideration, the details of design representations are examined by the jury members.
4	*Interruption of the presentation.* While the student(s) are presenting the design details, this presentation may be interrupted by jury members with some comments or questions to get further information if there is a missing part in relation to the presentation.
5	*Transition.* Towards the end of the presentation, while the activities of the student(s) are decreasing, jury members start to think about what comments to make and questions to ask considering the oral and visual presentation as a whole.
6	*Clarification.* At the end of the presentation, if needed, jury members can ask some questions for clarification on some parts of the presentation or request a detailed explanation about some parts of the project.
7	*Comments and discussion.* Jury members provide feedback with their negative and/or positive comments, and they make suggestions for further development or the points that the student should further explore. The student(s) listen(s) to the comments and answer(s) the arguments. In this phase, it is also possible that comments and critiques provided by the jury members may not be consistent; they may change according to the performance of the student(s). Therefore, there may occur disagreements and debates even within the jury itself. Moreover, this may cause the student(s) to be confused about the opinion of the jury on the project.
8	*Conclusion.* The student(s) and jury members agree on the comments for developing the project further, and the jury provides a grade.

It can be concluded that all processes and mechanisms of learning and teaching design in industrial design studio courses are based on reflective interactions and communications between students and instructors in these studio critiques described in detail above (Hough, 2013). In other words, these are the main studio-based practices of industrial design studio courses in which design knowledge and ideas are

transmitted and communicated between the actors of the courses (Goldschmidt et al., 2010; Hough, 2013; Uluoğlu, 2000).

2.1.5.2 Core tasks of students: representing and presenting design ideas[3]

Tovey (1997) states that to visualize the product concepts and to represent alternative solutions are two main responsibilities of industrial designers. In line with Tovey (1997), Green and Bonollo (2003) state that the design studio course which is the heart of industrial design education is a course in which "students learn to [visualize] and represent aspects of a problem graphically and to *think* as a designer" (p. 269). On the other hand, as mentioned in the previous section, all teaching and learning processes and mechanisms of industrial design education depend on transmitting and communicating design knowledge and ideas between students and other actors of the course such as peers, instructors, and invited professionals. This transmission and communication can only be possible if the student's internal dialogue becomes externalized. In other words, only representing and presenting design ideas opens the way for reflective dialog between students and instructors, or peers, etc. (Goldschmidt, 2004; Goldschmidt et al., 2010; Uluoğlu, 2000). According to Hough (2013), within studio critiques which are the main media of interaction and communication between students and instructors in industrial design education, if there is no design representation there is nothing to think about, or talk about.

Besides, design representations represent not only students' design ideas but also their steps taken during the project process conducted within the course (Hough, 2013). Through design representations produced by students at different phases of the project process, the progression process of students' ideas and interpretations, and results achieved can be tracked easily by both students themselves and instructors.

As a reflection of these arguments, it can be said that within the construct of the industrial design studio course, to represent and to present design ideas, product concepts, and solutions especially by using visual instruments are the two core tasks of the students.

[3] Discussions in this part of the thesis are published in the article entitled "An overview of virtual reality within industrial design education". doi: 10.1108/JEDT-02-2020-0048

2.2 Virtual Reality

2.2.1 Definitions of virtual reality

The phrase “Virtual Reality (VR)” was first introduced as a term by Jaron Lanier who is the founder of VPL Research founded in 1984 (Pimentel & Teixeira, 1997). Other interchangeably used phrases with “Virtual Reality” are “Artificial Reality” by Krueger et al. (1985), and “Cyberspace” used in a science fiction novel by William Gibson (Ye, 2005). “Virtual World” is another widely-used phrase with the same meaning with the term “Virtual Reality” (Ye, 2005; Ye et al., 2006).

The current dictionary definitions of “Virtual Reality”, which was once described by Ivan Sutherland (1965) as a system called the “Ultimate Display” that would include a visual monitor and an audio display to produce taste and smells, and even provide force feedback through a kinetic display (Henry, 2019), are as follows:

— “an artificial environment which is experienced through sensory stimuli (such as sights and sounds) provided by a computer and in which one's actions partially determine what happens in the environment” (Merriam-Webster, 2020)

— “a set of images and sounds, produced by a computer, that seem to represent a place or a situation that a person can take part in” (Cambridge Dictionary, 2020b)

— “images and sounds created by a computer that seem almost real to the user, who can interact with them by using sensors” (Oxford Advanced Learner’s Dictionary, 2020)

On the other hand, in the book named “The VR Book: Human-Centered Design for Virtual Reality”, the phrase “Virtual Reality” is used by Jerald (2015) not only as a term for “a computer-generated digital environment that can be experienced and interacted with as if that environment were real” (p. 9) but also as a notion for communication between human and technology, and refers to the collaboration between human and machine. According to him, although the word “communication” commonly refers to the interaction between two or more people, it can be abstractly considered as “the transfer of energy between two entities” just like the effect that occurs when an object collides with another one. From the standpoint of the user, the virtual reality environment is where s/he focuses on the experience rather than the technology itself. For this reason, the design of VR experience is related to “how the

virtual world works, how that world and its objects are controlled" (Jerald, 2015, p. 10).

2.2.2 Virtual reality within reality technologies

According to Milgram & Kishino (1994), reality can take various forms that fall somewhere along a "virtuality continuum" from the "real environment" to the "virtual environment" in Figure 2.5, where Virtual Reality corresponds to the "Virtual Environment" in this continuum.

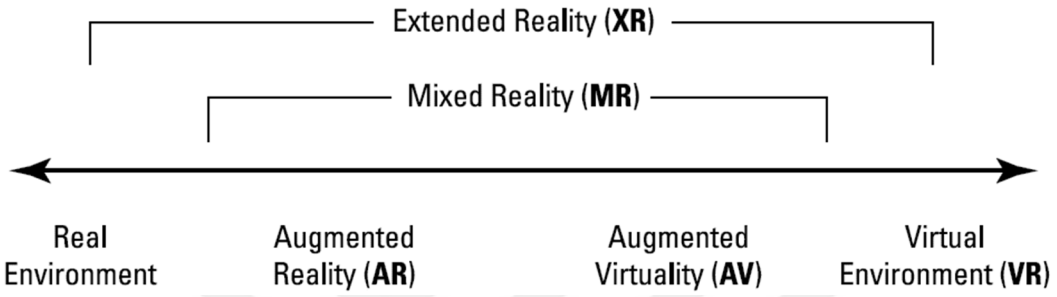


Figure 2.5 : Updated version of the virtuality continuum of Milgram & Kishino (1994), taken from (Mealy, 2018, p. 14).

"Mixed Reality (MR)" technology takes place somewhere between the real environment and the virtual environment and includes "Augmented Reality (AR)" and "Augmented Virtuality (AV)". This technology can be described as a technology that, by merging real and virtual worlds, produces new environments and visualizations where digital and physical objects exist together and interact with each other in real-time (Hara & Oda, 2012; Hilsmann & Eisert, 2009; Poh et al., 2011).

Of the other elements of the continuum, "Augmented Reality" can be roughly described as "a technology that adds an extra layer of virtual information on top of the perception of the real world, in real-time" (Loijens et al., 2017, p. 14) while "Augmented Virtuality" can be described as "the real-time representation of the current state of real-world elements in media and information technology" (Spacey, 2016). These two reality technologies are very similar in terms of blending digital objects that belong to the virtual world and physical objects in the real world. Main difference between them is where the interaction with the user occurs. In "Augmented Reality", this interaction occurs in the real world, whereas, in "Augmented Virtuality", it occurs in the virtual world (Spacey, 2016).

"Extended Reality" is a newly emerged umbrella term referring to the whole spectrum of reality technologies including VR, AV, AR, and MR (Mealy, 2018). In Figure 2.6 below, some examples of commercially available VR/AV/AR/MR systems, and technology providers are presented.

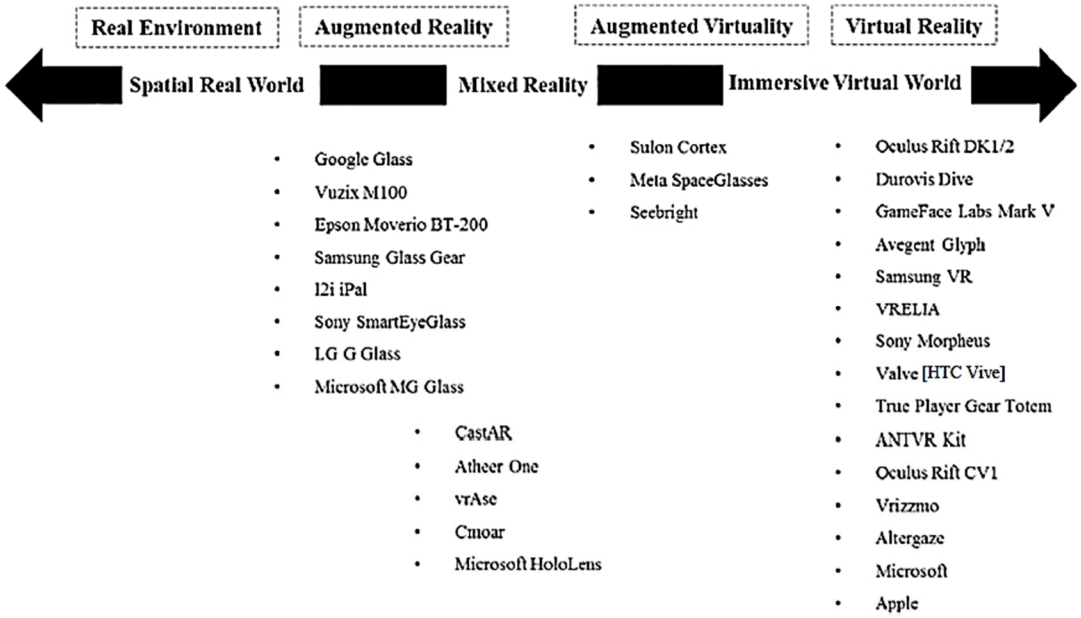


Figure 2.6 : Examples of commercially available VR/AV/AR/MR systems and technology providers, taken from (X. Li et al., 2018, p. 152).

2.2.3 Key elements of virtual reality experience

The key elements that establish the VR experience, and their descriptions derived from the literature are as follows:

— *Virtual world:* "an imaginary space often manifested through a medium" and "a description of a collection of objects in a space and the rules and relationships governing those objects" (Sherman & Craig, 2018, p. 7).

— *Immersion:* "the perception of being present in a non-physical world that allows the human brain to believe it is somewhere it is not" (PCWTA, 2017, p. 2).

- *Mental Immersion:* "deep mental state of engagement with suspension of disbelief that one is in a virtual environment" (PCWTA, 2017, p. 2).
- *Physical Immersion:* "physical engagement in a virtual environment with suspension of disbelief that one is in a virtual environment" (PCWTA, 2017, p. 2) by "synthetic stimulus of the body's senses via the use of technology" (Sherman & Craig, 2018, p. 9).

— *Presence (Telepresence/Imagination):* "Imagination, otherwise known as presence, is the feeling of being present or being a part of the computer generated world" (Bamodu & Ye, 2013, p. 1169). According to the International Society for Presence Research (2000),

> Presence (a shortened version of the term "telepresence") is a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. (International Society for Presence Research, 2000)

— *Sensory feedback:* "the selective provision of sensory data about the environment based on user input. The actions and position of the user provide a perspective on reality and determine what sensory feedback is given" (Sandler, 2014, p. 316).

— *Interactivity:* the response-ability of the system for the participant to continue to interact with the virtual world by feeling immersed and natural in the environment. "Delays in the ability to interact in the virtual environment can be disruptive" (p. 2) to the user (PCWTA, 2017).

— *Participants:* Muhanna (2015) sates that

> Participants vary in many dimensions … A new participant to a virtual reality system, for example, needs a system that minimizes the learnability aspect of its experience. An expert participant, on the other hand, needs an efficient system in terms of getting to his or her goal with the help of shortcuts and command aggregations. (p. 349)

2.2.4 Common types of virtual reality

According to Bamodu & Ye (2013) and PCWTA (2017), virtual reality systems are generally categorized into three major groups based on their immersion levels as "non-immersive", "semi-immersive", and "full(y)-immersive".

— *Non-Immersive VR systems:* These types of systems enable users to communicate with the virtual environment through a stereo display monitor with the help of a mouse, space ball controllers, and keyboard. They are also known as "Desktop VR", "Fish Tank Virtual Reality", and "Window on World (WoW) Systems"

(Bamodu & Ye, 2013). In these systems, only some of the participant's senses come into play, and the user's peripheral awareness of reality outside the virtual world continues (PCWTA, 2017). 3D modeling and CAD systems are also included in this group (Bamodu & Ye, 2013; Isdale, 1998).

— *Semi-Immersive VR systems:* These types of systems are also known as hybrid systems (Dani & Rajit, 1998), or augmented reality systems (Bamodu & Ye, 2013). In these systems, while the simplicity of non-immersive VR systems is met, the immersion level gets increased by using some physical models, objects, or equipment. Vehicle training/driving simulators and the CAVE (Cave Automatic Virtual Environment) are examples of this type of VR systems (Bamodu & Ye, 2013; Barrett, 2012).

— *Full(y)-Immersive VR systems:* These types of systems provide the highest level of immersion. In these systems, the user is encompassed by the computer-generated virtual environment with the help of HMD (Head-Mounted Display), tracking devices, data gloves, and other equipment. These systems can stimulate all senses of the participant (Bamodu & Ye, 2013; PCWTA, 2017).

2.2.5 Taxonomy of virtual reality systems

Based on "the type of technology used in building the system" and "the level of mental immersion", VR systems and their sub-categories are classified as seen in Figure 2.7 by Muhanna (2015). According to this taxonomy, VR systems are divided into two main groups, "basic" and "enhanced".

— *Basic VR systems:* These systems are screen-based and pointer-driven systems that do not need special input or output devices to view the VR environment (Heim, 2007). These systems can be classified into two sub-categories as hand-based VR systems (Figure 2.8) and monitor-based VR systems (Figure 2.9) (Muhanna, 2015).

  - *Hand-based VR systems:* Hand-held devices such as mobile phones, personal digital assistants, and portable game consoles.
  - *Monitor-based VR systems:* Desktop computers displaying three-dimensional graphics on monitors.

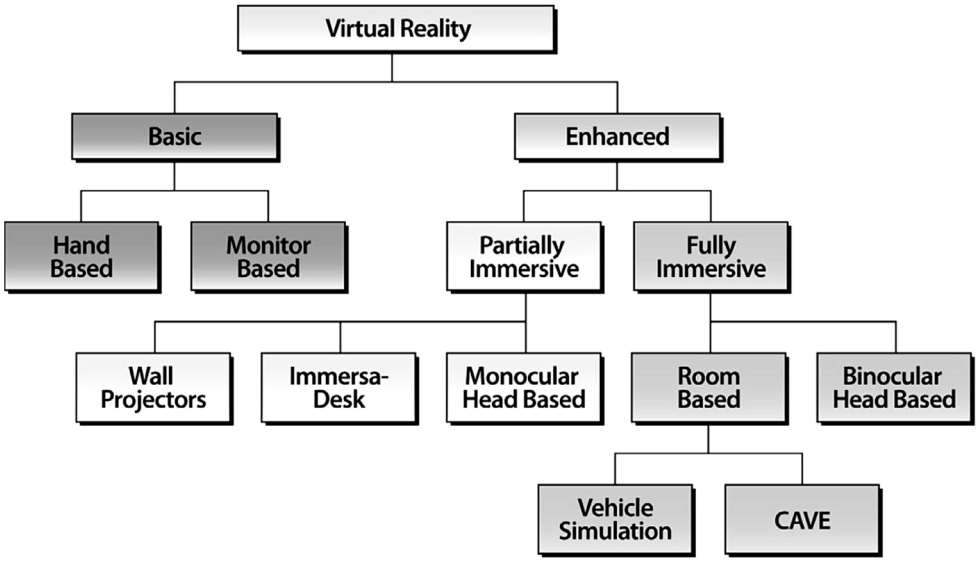


Figure 2.7 : Taxonomy of virtual reality systems, taken from (Muhanna, 2015, p. 349).

Figure 2.8 : An example of hand-based VR systems, taken from (URL-1).

Figure 2.9 : An example of monitor-based VR systems, taken from (URL-2).

— *Enhanced VR systems:* These systems require more powerful devices than those getting run in basic VR systems. VR experience provided by these enhanced systems can be full(y)-immersive or partially immersive in terms of the mental immersion factor. In partially immersive VR systems, a large digital screen or a single projector viewing the virtual world on a large screen is used whereas room-based setups or VR headsets are used in full(y)-immersive ones for getting the user to feel being in a 3D environment. Wall Projectors (Figure 2.10), ImmersaDesk (Figure 2.11), and Monocular Head Based systems (Figure 2.12) are the sub-categories of partially immersive VR systems (Muhanna, 2015).

Figure 2.10 : An example of enhanced wall projectors, taken from (URL-3).

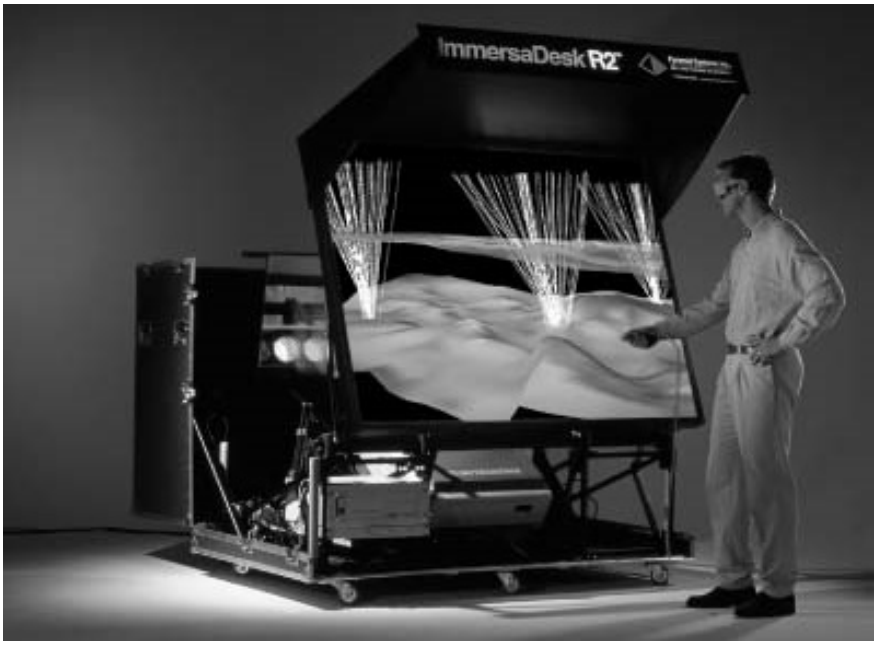


Figure 2.11 : ImmersaDesk, taken from (URL-4).

Figure 2.12 : An example of monocular head-based systems, adapted from (URL-5).

Binocular Head Based (Figure 2.13) and Room Based VR systems are the sub-categories of full(y)-immersive systems. Room based systems are also divided into two as Vehicle Simulation (Figure 2.14) and CAVE (Figure 2.15) (Muhanna, 2015).

Figure 2.13 : An example of binocular head-based systems, taken from (URL-6).

Figure 2.14 : An example of vehicle simulations, taken from (URL-7).

Figure 2.15 : CAVE (Cave Automatic Virtual Environment), taken from (URL-8).

According to the information presented in the last two sections (2.2.4 Common Types of Virtual Reality and 2.2.5 Taxonomy of Virtual Reality Systems), it can be said that the borders between non-immersive, semi-immersive, and full(y)-immersive VR systems are not so clear. For example, vehicle training/driving simulators and CAVE are accepted as semi-immersive in the classification by Bamodu & Ye (2013) and

PCWTA (2017), where they are included as full(y)-immersive VR systems in the taxonomy by Muhanna (2015). However, there is a consensus on VR experiences provided by VR headsets such as HTC Vive and Oculus Rift, and smartphone VR glasses such as Google Cardboard and Google Daydream are full(y)-immersive.

2.2.6 Hardware and software in virtual reality systems

VR systems typically consist of a combination of hardware and software.

2.2.6.1 Hardware

Hardware is responsible for: collecting the signals (about the user's actions) from input devices; running software to process these signals; and conveying the signals about the system's reaction to output devices. The hardware used in VR systems contains a processor, display, sensors, and input/output devices (X. Li et al., 2018). The principal components of hardware are input and output devices since they are key determinants of the user's experience in the VR environment (Anthes et al., 2016; Kim et al., 2020; X. Li et al., 2018; Zhang, 2017).

Input devices

Input devices in VR systems are devices, such as cameras, mouse/gamepads, joysticks, microphones, sensors, and accelerometers, capturing the user's physical actions, converting them into digital signals, and delivering them to the software for processing. These devices can be handheld, wearable, and/or spatial. A wide variety of things like movements, images, sounds, accelerations, orientations, etc. can be captured by these devices as an input. Current input devices are presented in Figure 2.16 and Figure 2.17 with the classification by Anthes et al. (2016) and Li et al. (2018). Input devices used in VR systems can be categorized, as well, by regarding their relationships with hands and by whether they can be tracked or not, as can be seen in Figure 2.18 (Kim et al., 2020).

Output devices

Output devices in VR systems are devices, such as glasses, digital displays, projectors, speakers, headphones, controllers, etc. delivering the signals provided by the system as a reaction to the user's physical actions to the user by converting them into sensory feedbacks. These feedbacks can be in a wide variety of forms such as images, motions, vibrations, sounds, smells, and tastes. Current output devices are presented in Figure

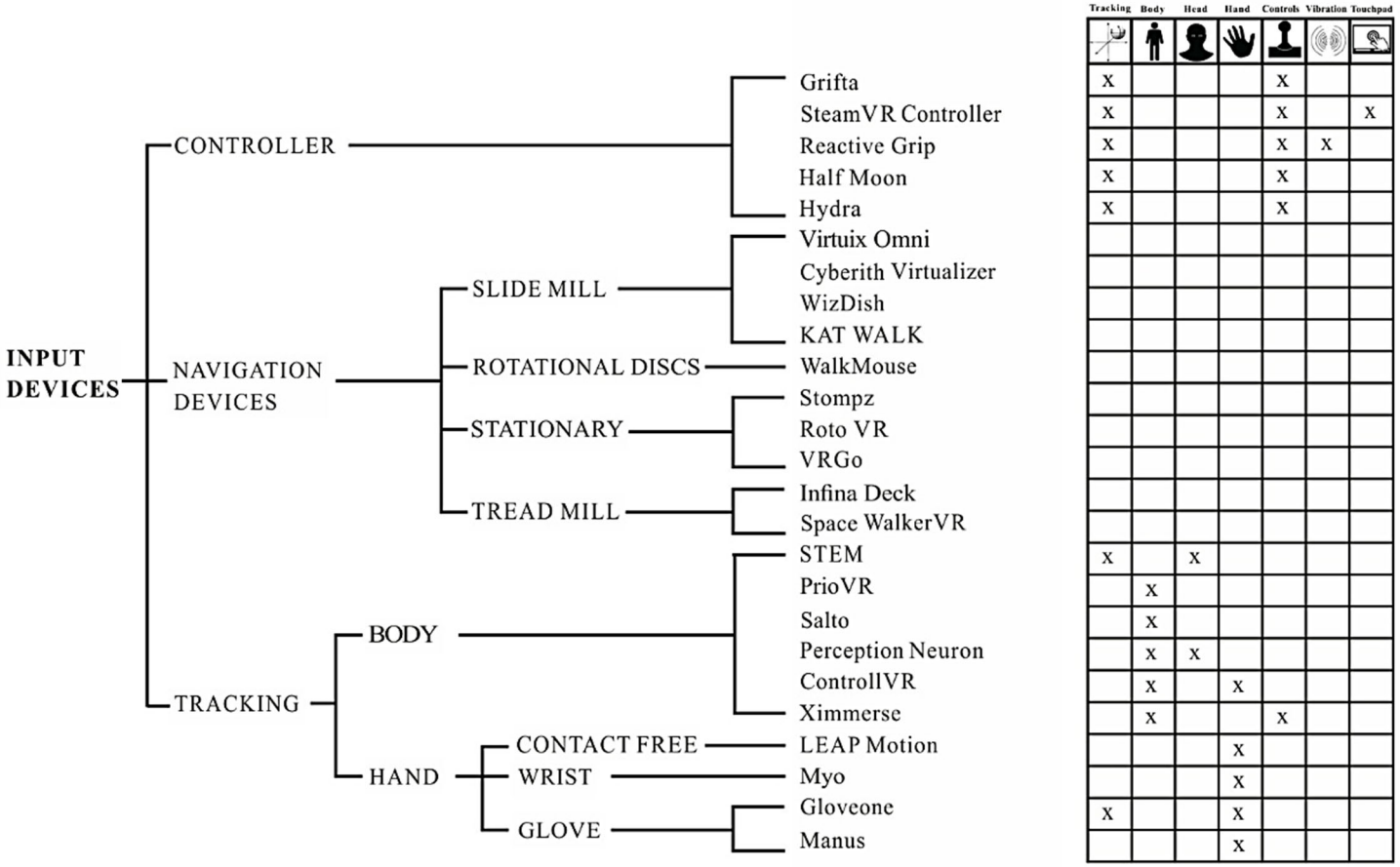


Figure 2.16 : Taxonomy of the VR input devices, taken from (Anthes et al., 2016, p. 4).

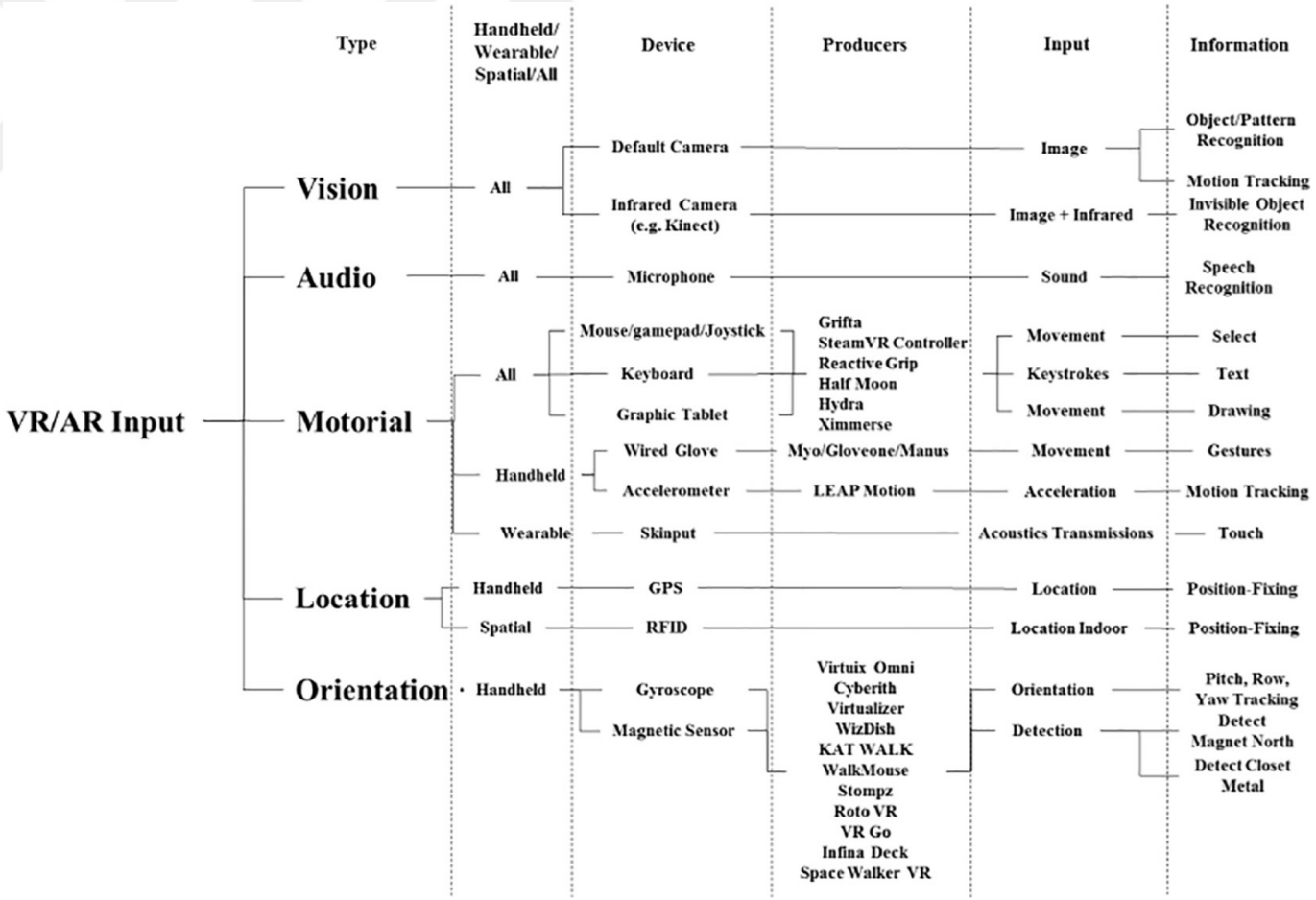


Figure 2.17 : Taxonomy of VR/AR input devices, taken from (X. Li et al., 2018, p. 154).

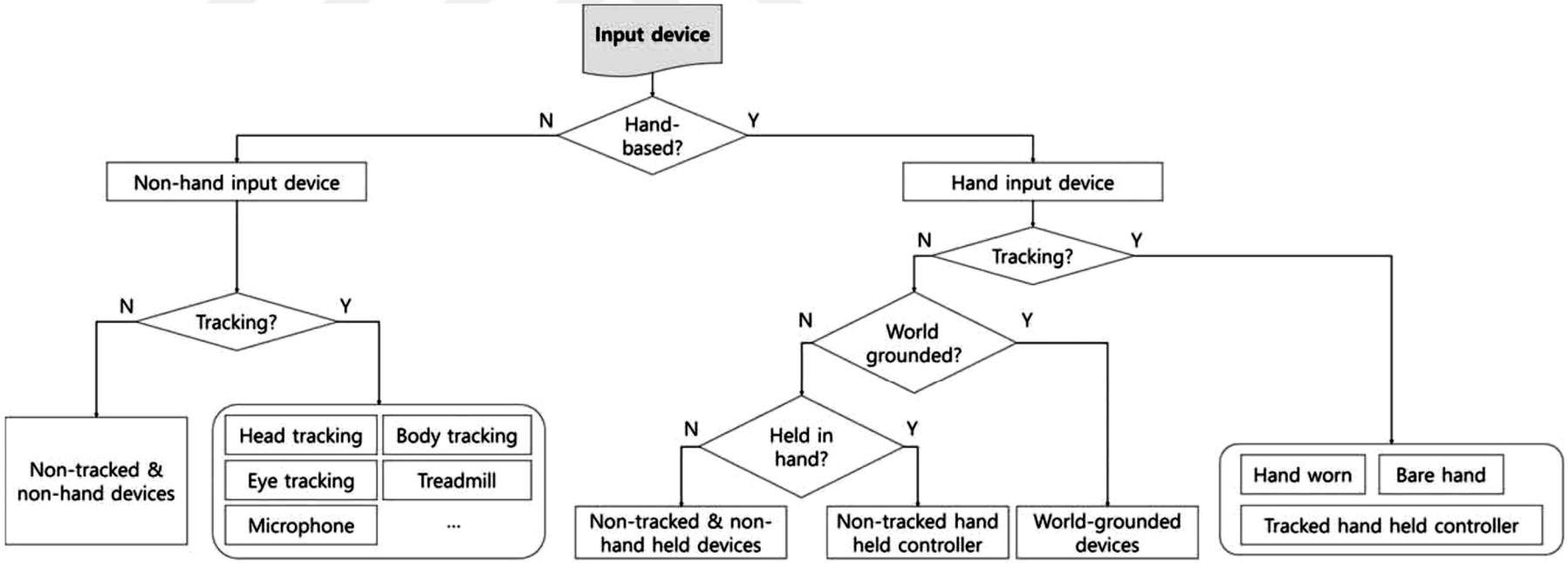


Figure 2.18 : Taxonomy of input devices in VR systems, taken from (Kim et al., 2020, p. 896).

2.19 and Figure 2.20 with the classification by Anthes et al. (2016) and Li et al. (2018). Another categorization regarding these devices belongs to Kim et al. (2020), and it is presented in Figure 2.21 as well.

2.2.6.2 Software

There are excessive amounts of software used for different purposes such as for creating the VR scene; for experiencing the created VR scene; and for developing VR applications. 3D modeling software, game engines, and simulation software are the main types of these. All 3D modeling software such as 3ds Max and Rhinoceros can be used for creating a VR scene. However, VR scenes created with these types of software may require additional plug-ins or other software for experiencing them with full(y)-immersive VR devices. On the other hand, game engines such as Unity and Unreal Engine, or simulation software such as SimLab Composer, allow both to create a VR scene and to directly experience it with full(y)-immersive VR devices. Also, VR scenes created with 3D modelling software can be experienced by importing them into these game engines, or into simulation software.

2.3 Possible Applications of Virtual Reality in Design Processes

Coburn (2017) states that VR, in design processes, can be utilized;

- as an *empathy development tool* in the opportunity development phase,
- as an *inspiration tool* in the ideation and conceptual design phases,
- as *CAD, analysis, data visualization, design review, and virtual prototyping (virtual reality prototype – VRP and interactive virtual prototype - iVP) tools* in the preliminary and detailed design phases,
- as *virtual manufacturing, virtual assembly, and virtual disassembly tool* in the producibility refinement phase,
- as a *maintenance/serviceability analysis tool* in the post release support phase (Figure 2.22).

He describes the reasons behind these statements as follows.

Empathy Aid: Developing empathy for the end-user of the product is a requirement for designers to create successful user-centered products and it has crucial importance for a better understanding of the user's needs. Also, it motivates designers for designing products that meet user needs (Fritsch et al., 2007; Kouprie & Visser, 2009). In the *opportunity development phase* of the design process, designers generally try to

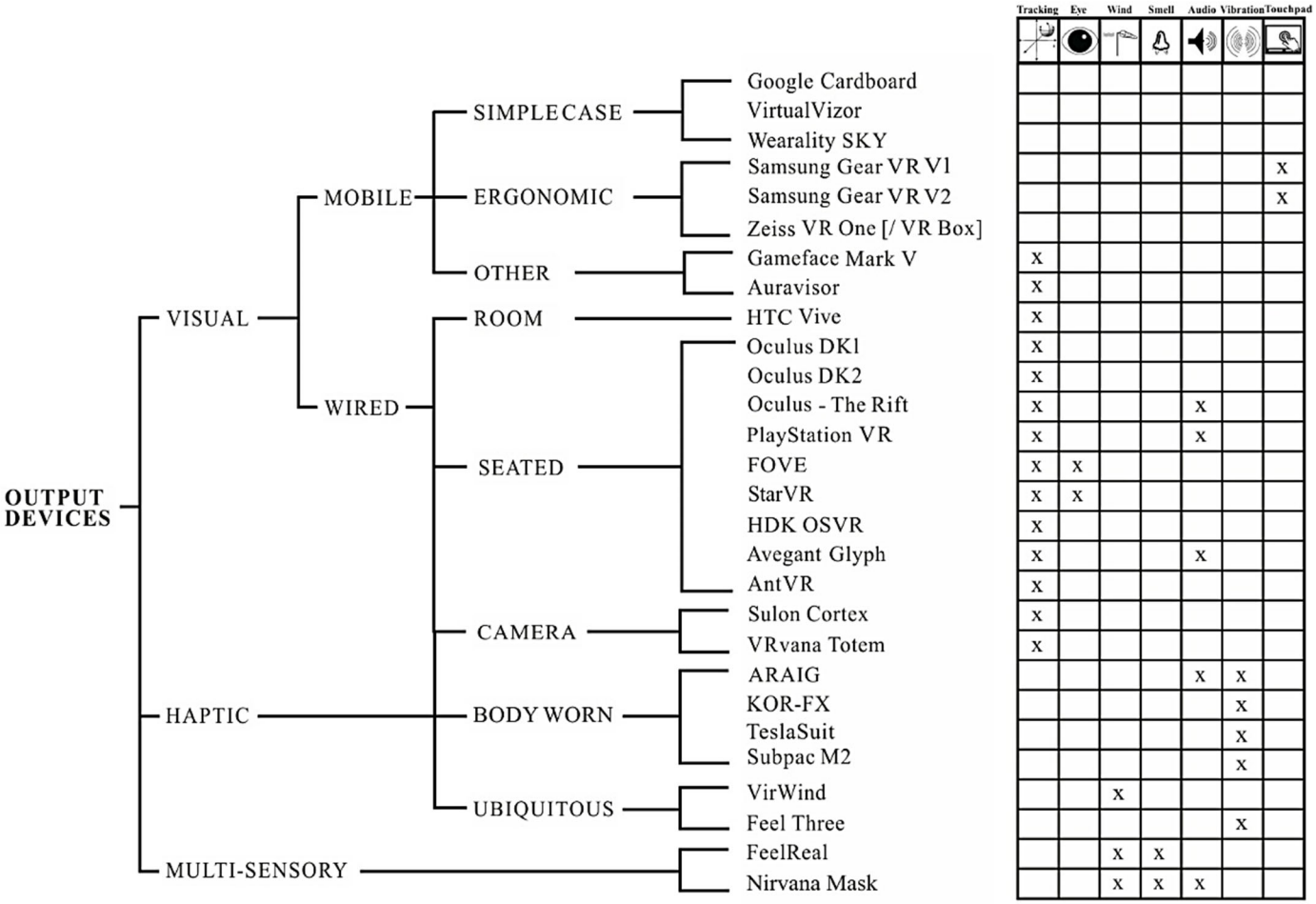


Figure 2.19 : Taxonomy of the VR output devices, taken from (Anthes et al., 2016, p. 4).

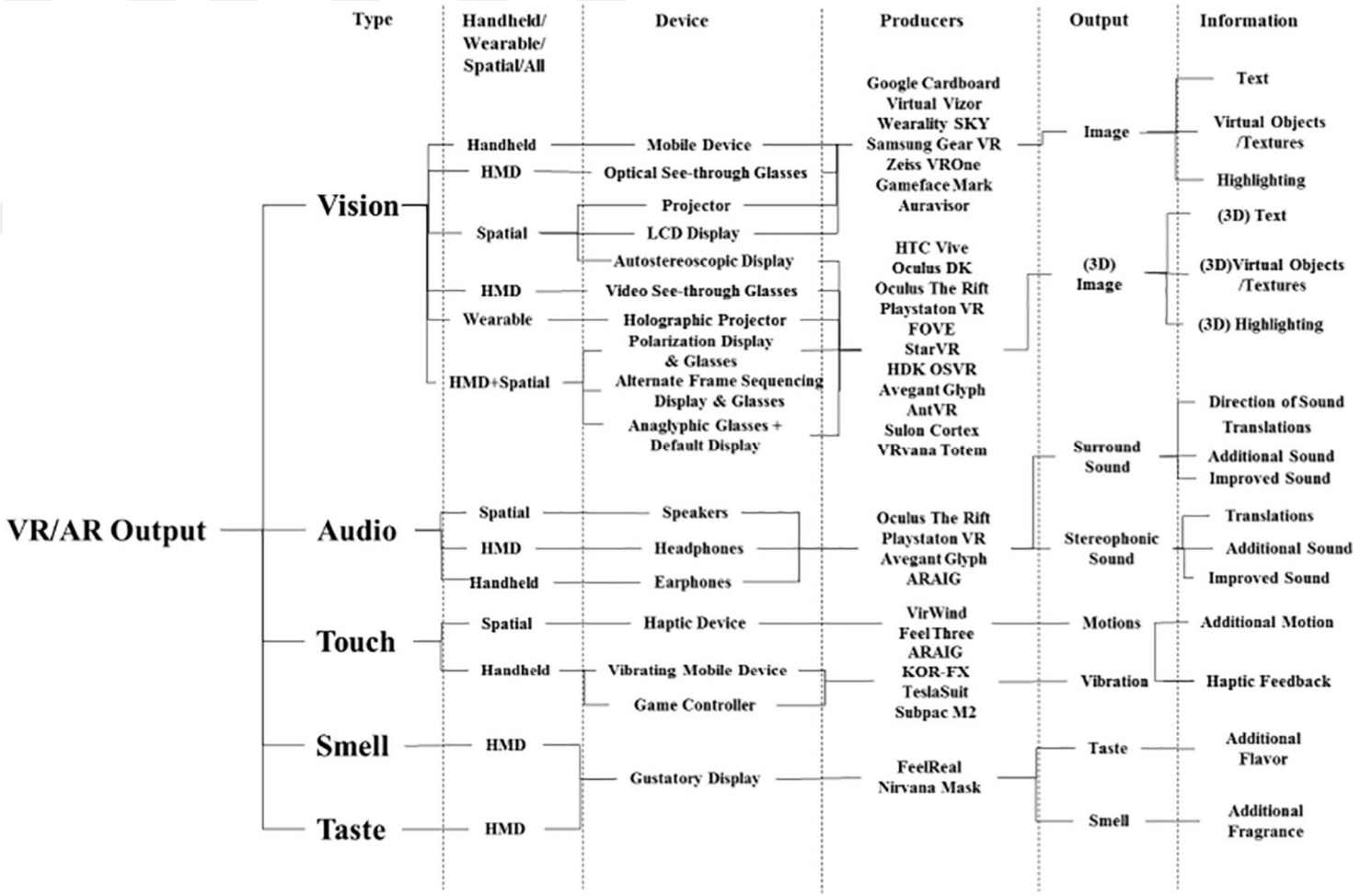


Figure 2.20 : Taxonomy of VR/AR output devices, taken from (X. Li et al., 2018, p. 155).

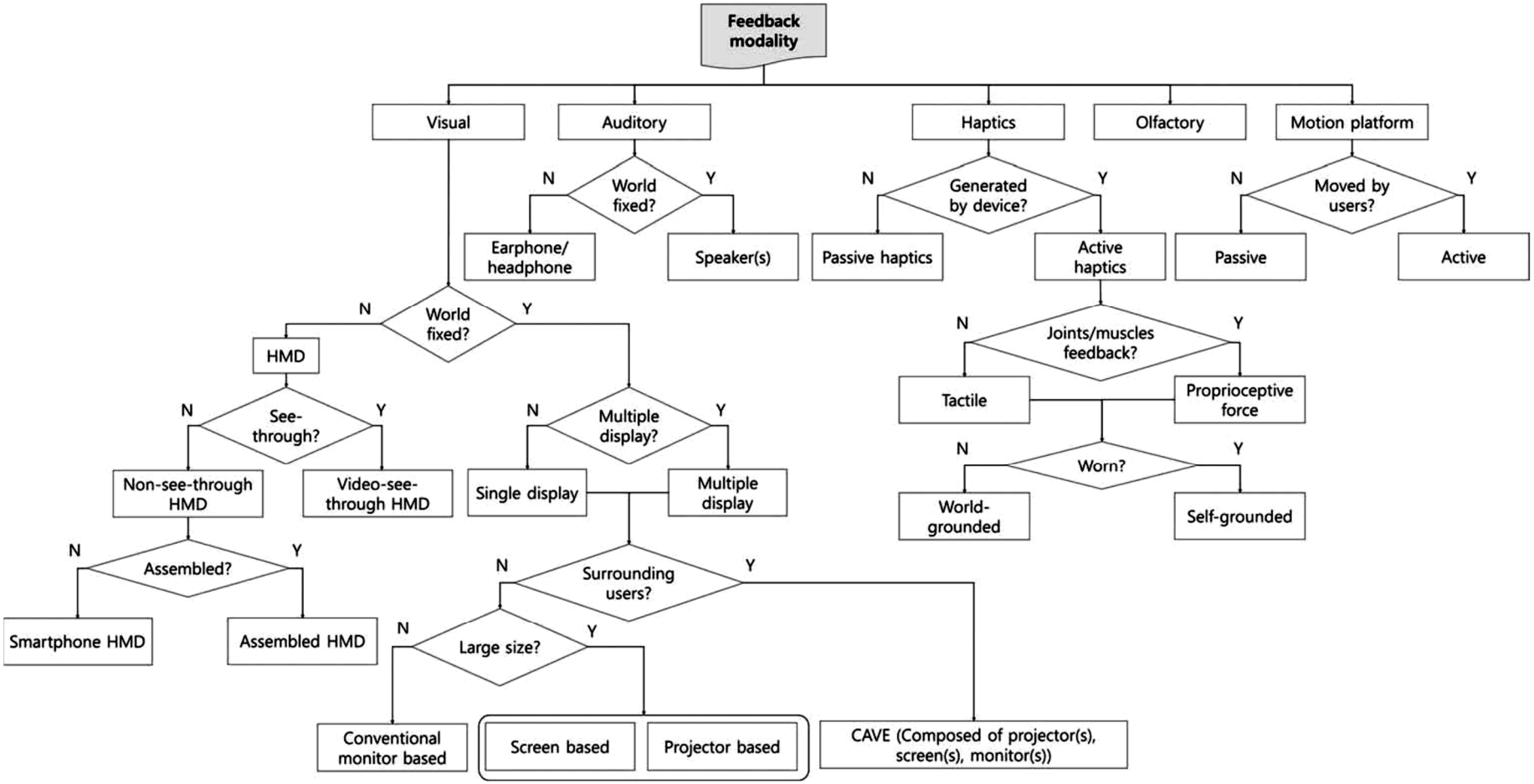


Figure 2.21 : Taxonomy of output devices in VR systems, taken from (Kim et al., 2020, p. 896).

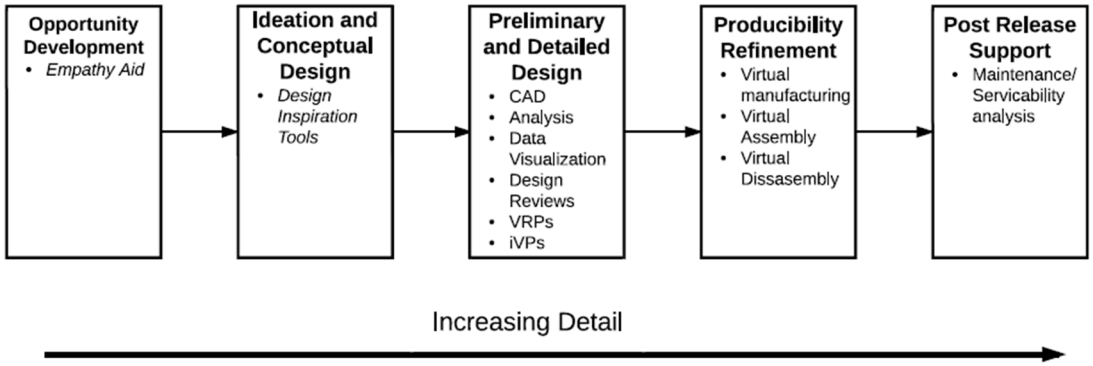


Figure 2.22 : Possible applications of virtual reality in design processes, taken from (Coburn, 2017, p. 41).

develop empathy through shared experiences. However, VR offers a novel and effective way of developing empathy by experiencing the situation directly (Coburn, 2017). For this reason, VR can be used as an empathy development tool in designing.

Design Inspiration: In the *ideation and conceptual design phases*, designers try to draw inspiration from a wide variety of sources due to the fact that new ideas can only be generated by synthesizing previous knowledge and experiences (Coburn, 2017; Gonçalves et al., 2014; Ward, 1994). The inspiration needed by designers can be gained from closely, distantly, or unrelated sources (Chan et al., 2018). One of the key factors in the process of getting inspiration is the time allocated for this process. The more time and effort spent to seek out inspiration and the more objects examined, the more qualified and quantified ideas are generated (Eckert & Stacey, 1998). However, examining or experiencing more objects also means more costs. VR has the potential both for facilitating this inspiration process and for reducing costs.

CAD and Analysis: CAD software is a frequently used tool in *preliminary and detailed design phases* for creating 3D representations of the designed object. However, enhanced spatial reasoning is required for understanding these representations on a 2D screen (Hsi et al., 1997). 3D modeling can be performed more intuitively in a full(y)-immersive virtual environment. This requires fewer skills for spatial reasoning, and provides easier and better understanding (Bryson, 1996). By its facilitating features, VR also enables especially non-analysts to perform 3D analyses, and to interpret the results of these analyses more easily (Connell & Tullberg, 2002).

Visualization: VR can also be used as a platform for data visualization and makes interacting with higher dimensional data more meaningful. (Coburn, 2017). It provides

better perception and a more intuitive understanding of the geometry, and make keeping the perceived relationships in mind easier (Donalek et al., 2014).

Design Review: The design review step is one of the highly valued steps in design process in which many vital decisions regarding the product – that is the outcome of the process – are made. Collaborative virtual environments allow designers both to share information with others and to interact with each other by interacting with design representations (Churchill & Snowdon, 1998).

Virtual Prototyping: In the proposal by Coburn (2017), VRP (Virtual Reality Prototype) refers to the virtual prototype and iVP (interactive Virtual Prototype) refers to a subset of the virtual prototype. Virtual prototyping enables the 3D design representations to be rendered and viewed in a virtual environment that is the simulation of the context in which the product would be used. In this way, it provides a much more realistic and effective aesthetic evaluation. By using advanced input and output devices such as haptics, sensors, and VR gloves, virtual prototypes can also be used for usability and/or ergonomic evaluation of the designed product. Based on these evaluations, making changes to the virtual prototype can be performed more quickly in contrast with physical prototyping. Moreover, building a detailed physical prototype can require a high cost. This is one of the reasons that physical prototypes are usually not employed in the early stages of design. However, the costs of virtual prototyping are much lower. For this reason, it can allow much more evaluation of concepts and models in the early stages of design process. Virtual prototypes also offer some advantages for market research. For example, virtual prototypes created with parametric CAD software allow market specialists to evaluate a large number of design variations with users in one session (Coburn, 2017).

Producibility Refinement: "Design for manufacturing" and "design for assembly" are two design areas serving for reducing costs and time to launch a product. The effort for employing and integrating these activities earlier in the design process is a continuous effort in new product development. With the help of interactive virtual prototypes, the *manufacturing* and the *assembly* steps can be simulated in high-fidelity level, and these prototypes can be quickly and iteratively changed so as to refine the manufacturability of the designed product (Coburn, 2017).

Post-release Support: As the systems and/or mechanisms contained by the product become more complex and more expensive, designing maintainability and serviceability of it becomes more important and more difficult (Eubanks & Ishii, 1993). One of the major difficulties is that performing an accurate analysis of the product's maintainability can only be possible with the creation of high fidelity prototypes (Ishii et al., 1993). Verification of the maintainability through simulations with CAD software is one of the practical ways used for overcoming this difficulty (Gynn & Steele, 2015). However, performing an analysis with this method can be time-consuming. Also, the use of simulated human models in the analysis can cause a lack of fidelity. Yet, VR simulations performed by using advanced controllers allow designers to analyze the maintenance scenarios close to real conditions (Coburn, 2017).

Although Coburn (2017, pp. 40-51) presents a framework regarding the use of VR in design processes, his statements are not based on, in his own words, "a comprehensive review of all of the research in this area" (p. 40). For this reason, this issue is readdressed in the section "5.1.1 Systematic literature review on related works".

2.4 Summary

The literature review shows that industrial design is an iterative process that: proceeds through representations; employs creativity to resolve problems or create solutions; and a process through which products, devices, objects, services, and experiences are created, made fit with user needs, and developed. All designing mechanisms in this process are based on representing design ideas, in other words, making these ideas visible. This means that showing a thing that does not exist yet as if it exists. On the other hand, VR technology is a computer-based technology that makes it possible at high-fidelity level without the need for any physical material. By this opportunity, it can be employed in design processes as a(n);

- empathy development tool,
- inspiration tool,
- CAD tool,
- analysis tool,

— data visualization tool,

— design review tool,

— virtual prototyping tool,

— virtual assembly/disassembly tool, and

— maintenance/serviceability analysis tool.

Secondly, industrial design education is based on the theatrical simulations of the professional practices of industrial design, and it consists of a studio-based process that proceeds by following workflows and methods used by professional designers to conduct design project processes. In the educational setting of industrial design studio courses, studio critiques (formal or not) are the main studio-based practices. In the studio critique sessions of industrial design education, students try to explain their design ideas with the help of their representations, whereas instructors try to understand and evaluate these ideas by examining their representations and listening to students' explanations so that they can help and guide them by giving feedback. In other words, representing and presenting design ideas are the core responsibilities of students, and giving feedback by evaluating these ideas is the core duty of instructors, as design knowledge and ideas can only be transmitted and communicated in this way between them.

3. THEORETICAL FRAMEWORK

This chapter presents the theories and the models on which this thesis is based.

3.1 Designing and Virtual Reality within The Perspective of Design Theory [4]

As mentioned before, Vasari (1960) claims that "design is not other than a visible expression and declaration of our inner conception" (p. 205). According to Hill (2003), it means "a direct link between an idea and a thing" (p. 165). Lawrence (in Buchanan, 2000, p. 4) describes it as "the process and the result of giving tangible form to human ideas". Nelson & Stolterman (2003) state that "design is the ability to imagine that which does not yet exist, to make it appear in concrete form" (p. 10). In the book "Delft Design Guide" (Van Boeijen & Daalhuizen, 2010), it is accepted as "to conceive the idea for some artifact or system and to express that idea in an embodiable form" (Part 1 | Product Design in Delft – 1.1). According to Goldschmidt (2004), "design is to represent, and in no case is there design without representation" (p. 203). Based on these statements, "design" can be theoretically treated as design ideas that are made visible or real, and accordingly, the act of designing can be considered as the act of making invisible design ideas visible or real (Hamurcu et al., 2020; Welch, 2007). This means that there are two ways for a designer to turn the design idea in his/her mind into design: to show it as if real, or to make or produce it really. However, "bringing the 'real' entity into being is a task that usually falls into realms other than design, and actors other than designers (e.g. builders and manufacturers) are responsible for it" (Goldschmidt, 2004, p. 203). Therefore, designing, or the act of designing, can be accepted as an effort to show a product that does not yet exist as if it exists. On the other hand, it is possible to create the model of a product, which does not yet exist physically, in full scale within a Cartesian map with the help of CAD technology. However, it will be viewed and experienced with an arbitrary and fluid zoom factor if it is viewed on a digital screen, or on a projector screen. This causes loss both in

[4] Discussions in this part of the thesis are published in the article entitled "An overview of virtual reality within industrial design education". doi 10.1108/JEDT-02-2020-0048

reference and scale-awareness (Dorta et al., 2016). To experience a product that does not yet exist as if it really exists is only possible with VR technologies which enable one to experience a CAD model as if it exists in the real world deprived of any physical entity rather than acting as a viewing tool itself (Hamurcu et al., 2020).

Designing is also an iterative and creative process. According to Ulrich & Eppinger (2003), industrial design process is a sub-process of (new) product development process which is separated from manufacturing processes (Figure 2.7 in Chapter 2). Similarly, according to the model called "Double Diamond" of Design Council (2005), industrial design process has four consecutive phases: "Discover", "Define", "Develop", and "Deliver". The model ends with deciding on one solution that works and making it get ready for manufacturing processes. In the well-known book "Delft Design Guide" (Van Boeijen et al., 2013), industrial design process is, as well, finished by articulating and simulating design proposals, and manufacturing processes are not included.

On the other hand, "designer's area" is described by Cross (1983) as between "ill-defined problem" and "well-defined solution". Based on this argument, it can be said that designing begins with an idea generated in response to the defined problem. The word "idea", according to the definition of Audi (1995), refers to mental representational images of something. So, it is a virtual thing. Hence, in this case, it can be said that designing begins with a virtual idea. And, according to the stages of the industrial design process proposed by the Design Council and Delft Design Guide mentioned above, "Define" phase is the second phase following "Discover" phase, and the problem is defined in this phase. Therefore, it can be said that industrial design process has a sub-process that begins at the end of "Define" phase which can be called as the "act of designing" process. Pei (2009) defines the "act of design[ing]" as a process in which "mental images are first visualized and then processed" (p. 127). Self et al. (2009) describe it as a practice that consists of three generic stages: concept design, development design, and detail design. On the other hand, Galle (1999) associates the boundaries of the designing process with the production of design representations. He defines "designing itself as the production of a design representation" (p. 58). Accordingly, it can be seen that all types of design representations that were categorized in detail in the study by Pei et al. (2011) are produced in the aforementioned three generic stages. So, the act of designing

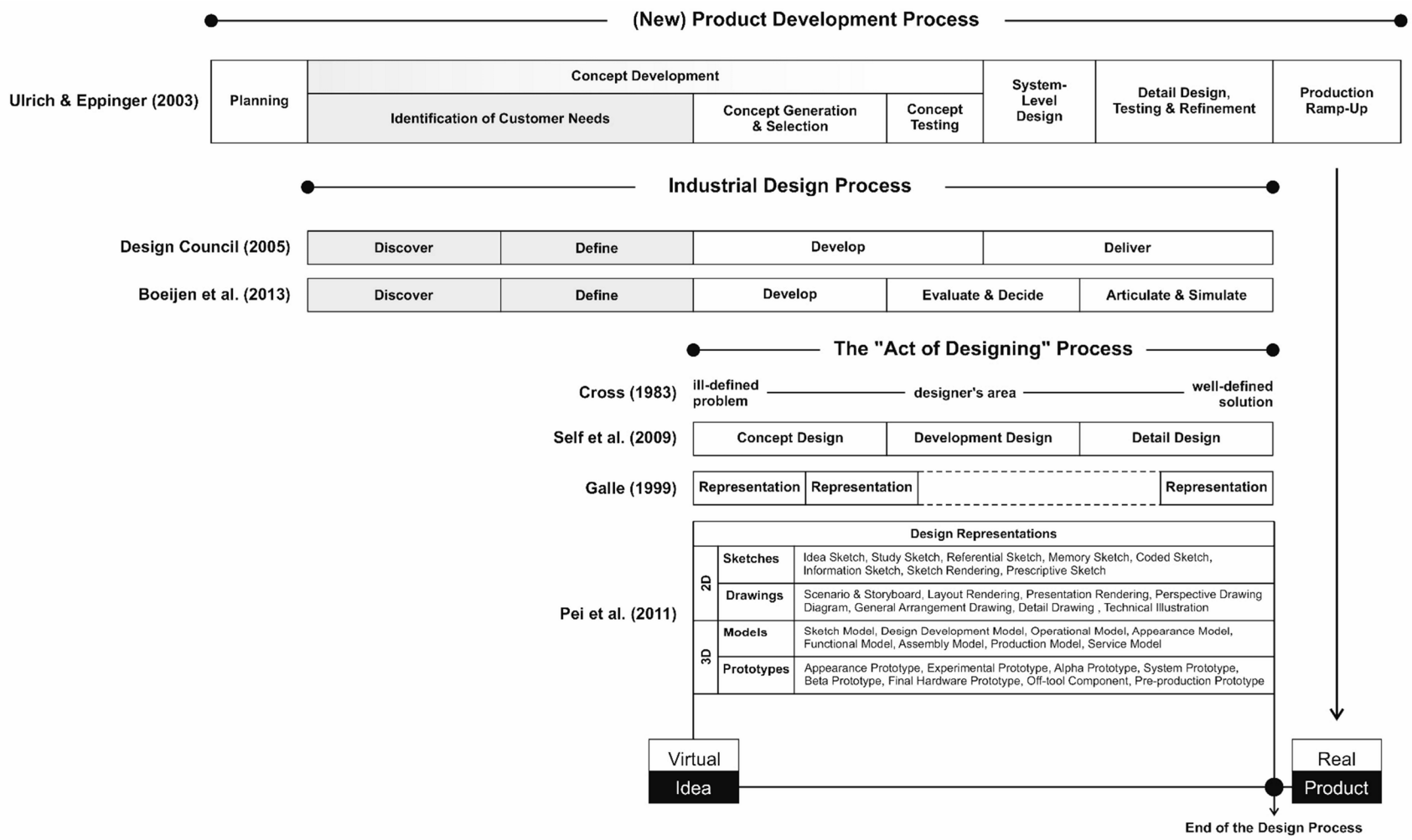


Figure 3.1 : Relations between the industrial design process and VR, taken from (Hamurcu et al., 2020, p. 1899).

beginning with a virtual idea proceeds towards a real product thanks to design representations generated in *concept design, development design,* and *detail design* phases. However, at the point closest to real, it ends just before realization (Figure 3.1). Therefore, its outcomes are highly realistic representations, in other words, "virtually real" representations.

All in all, designing can also be defined as an effort to show a product that does not yet exist as if it exists, whereas VR is the technology that makes it possible at high-fidelity level without any need for a physical material.

3.2 Design Representation and Virtual Reality within The Perspective of Communication Theory

Throughout the design process of a product, designers also embed their intentions regarding the form, function, and meaning of that product into it. These intents contained in the final product are passively perceived or received by users. This relationship between what the designer intends when designing the product and how these intents are interpreted afterwards by the user is considered as a type of communication (Crilly et al., 2008). In the literature, there are various diagrammatic representations developed by design theorists based on the existing communication models (Figure 3.2) which depict this communication process. The prominent ones are presented in Figure 3.3.

According to these models, products also function as messages of designers regarding their design intents. Likewise, in industrial design education, design representations produced by students not only make design ideas in their minds visible but also work as agents conveying the reasons behind design decisions to others such as instructors and peers. Timur (2002) states that,

> Design on paper, or on the computer screen, which is a project, is a signifier, whose referent does not physically exist at that stage. It means the signified is a mental picture. […] A sketch or a drawing conveys much more than a word (linguistic sign) or a statement. […] The baby (the design) is born out of a simulation of its future life. Like a mirror image, the storyboard of a life is constructed by the development of the product. The surface of the mirror corresponds to the product here, because like the shiny surface of the mirror,

the product is used to project something through. The product at this stage acts like a virtual mirror reflecting a virtual scenario, from future to present. All representations of this future life is done to simulate it as close to reality as possible. (pp. 62–63)

On the other hand, as mentioned before, VR also means communication between human and technology (Jerald, 2015). However, in this context, it can also be considered as a technology providing a medium in which reviewers can intuitively and naturally communicate with design representations, in other words, with design intents embedded into design representations.

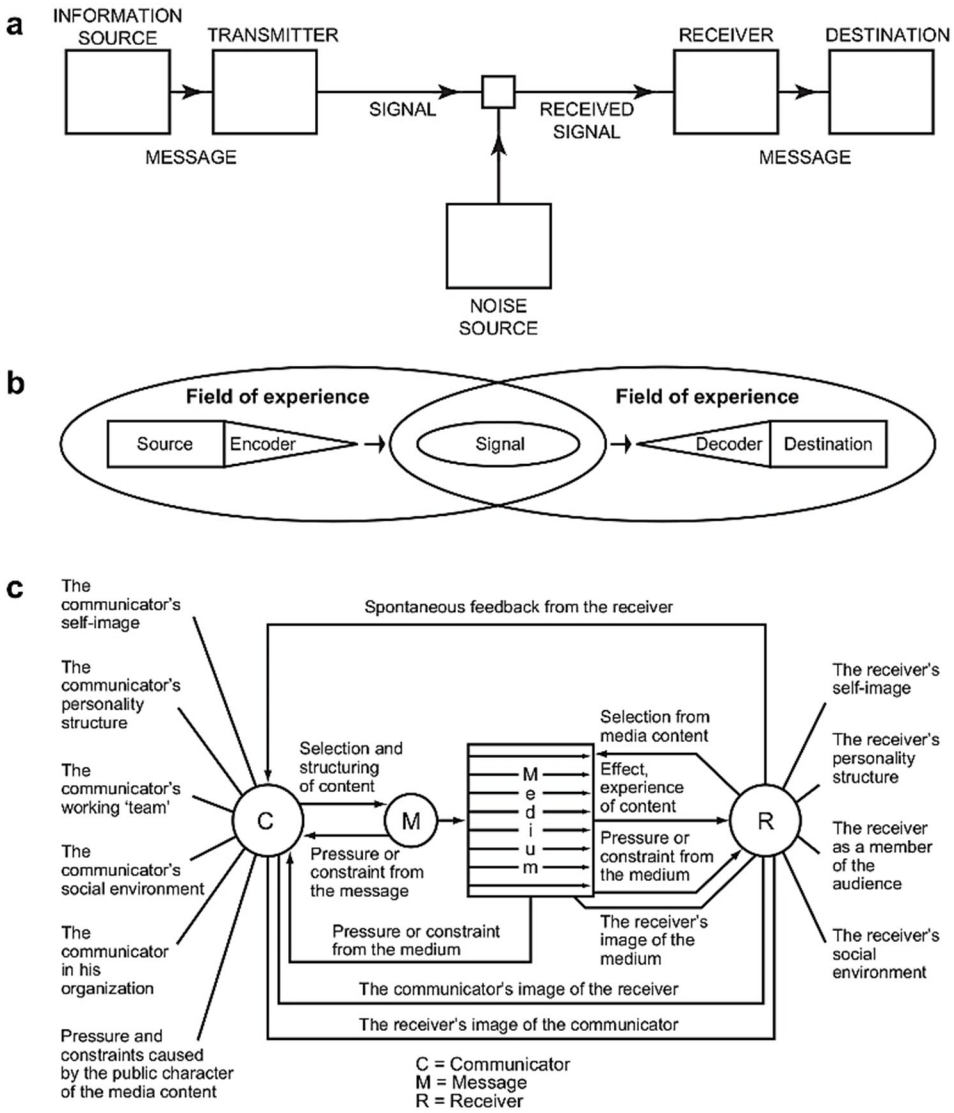


Figure 3.2 : Three communication models: (a) Shannon (2001) (Shannon–Weaver model), (b) Schramm (1971), (c) Maletzke (1981), taken from (Crilly et al., 2008, p. 431).

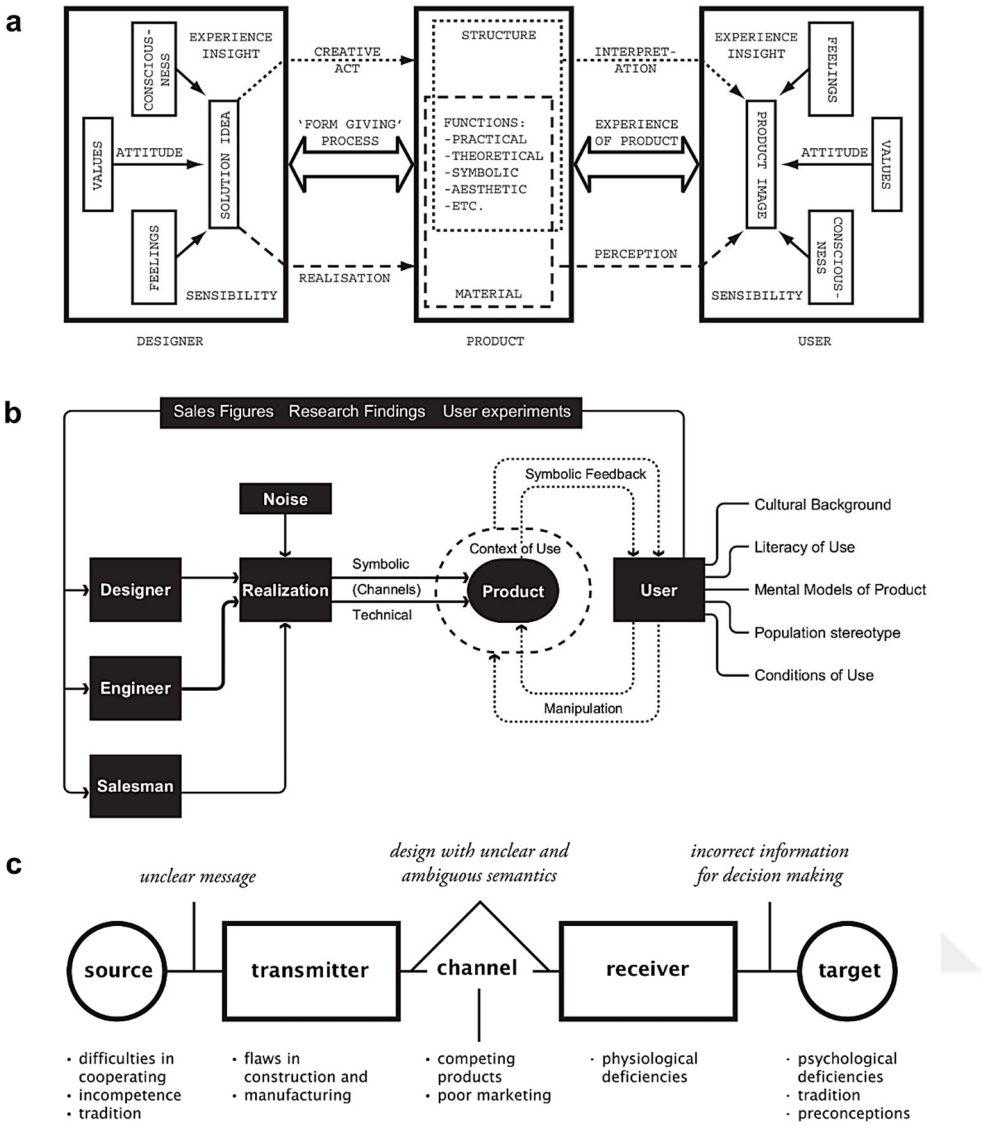


Figure 3.3 : Three design-specific communication models: (a) Maser (1976), (b) Krippendorff & Butter (1984), (c) Monö (1997), taken from (Crilly et al., 2008, p. 433).

3.3 Technology Acceptance Models and Theories

According to Louho et al. (2006), "technology acceptance is mostly about how people accept and adopt some technology to use" (p.15). Dillon (2001) states that user's acceptance of technology is evaluated by his/her willingness to use and that it "can be defined as the demonstrable willingness within a user group to employ information technology for the tasks it is designed to support" (p. 673). Hence, acceptance which can be "conceptualized as an outcome variable in a psychological process that users go through in making decisions about technology" (Dillon & Morris, 1996, p. 8) is also one of the crucial indicators of success, or failure, of that technology

(Samaradiwakara & Gunawardena, 2014). Many theories and models were developed to explain and to predict the technology acceptance of users especially based on the theories and the models from behavioral, social, and cognitive sciences. Base theories used to develop technology acceptance theories and models are presented along with their claims in Table 3.1., and well-known technology acceptance models and theories are presented with their brief descriptions consecutively.

Table 3.1 : Base theories for technology acceptance.

Theory	Claim
Cognitive Dissonance Theory (CDT)	It was formulated by Festinger (1957) and claims that "users may experience cognitive dissonance or psychological tension if their pre-acceptance usefulness perceptions are disconfirmed during actual use" (Bhattacherjee, 2001, p. 357).
Expectation-Disconfirmation Theory (EDT)	It was formulated by Oliver (1980) and claims that users "have expectations about a product and the product's perceived performance" (Changchit & Klaus, 2020, p. 85) and the user's "perception of overall satisfaction results from a comparison between expectation and outcome performance" (Huang, 2015, p. 12)
Theory of Reasoned Action (TRA)	The determinants of individual's behavior are his/her beliefs, attitudes and intentions (Fishbein & Ajzen, 1975)
Theory of Planned Behavior (TPB)	In addition to the constructs of TRA, "perceived behavioral control" described as "the perceived ease or difficulty of performing the behavior" affects behavior intention or actual behavior as well (Ajzen, 1991)
Social Cognitive Theory (SCT)	Behavior, personal factors, and external factors are the reciprocal determinants (Bandura, 1986)
Innovation Diffusion Theory (IDT)	Relative advantage, complexity, compatibility, trialability, and observability are the determinant features of an innovation that influence its adoption and acceptance (Rogers, 1995) [Also known as Diffusion of Innovation (DOI)]
Motivation Theory / Motivational Model (MM)	Individuals' behavior depends on extrinsic motivations such as "achieving valued outcomes" (Davis et al., 1992, p. 1112), and intrinsic motivations related to performing the behavior "in order to experience pleasure and satisfaction inherent in the activity" (Vallerand, 1997, p. 271).

3.3.1 Technology acceptance models

In this section, well-known technology acceptance models in the literature are presented with their brief descriptions.

3.3.1.1 Model of PC utilization (MPCU)

Model of PC utilization (MPCU) was developed based on the theories TRA and TPB by Thompson et al. (1991). This model is more suitable for predicting individuals' usage behavior rather than their intention to use (Samaradiwakara & Gunawardena, 2014).

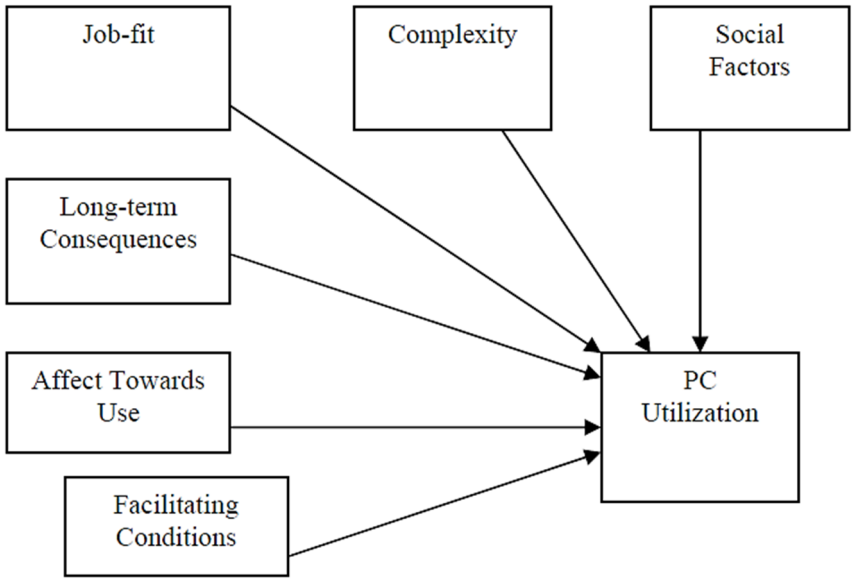


Figure 3.4 : Model of PC Utilization (MPCU), taken from (L. Li, 2010, p. 8).

In the model of PC utilization presented in Figure 3.4;

— *Social Factors* refers to "the individual's internalization of the reference groups' subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations" (Triandis, 1980, p. 210),

— *Complexity* refers to "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers & Shoemaker, 1971, p. 154),

— *Job-fit* refers to "the extent to which an individual believes that using a PC can enhance the performance of his or her job" (Thompson et al., 1991, p. 129),

— *Long-term Consequences* refers to the "outcomes that have a pay-off in the future, such as increasing the flexibility to change jobs or increasing the opportunities for more meaningful" (Thompson et al., 1991, p. 129),

— *Affect Towards Use* refers to "feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act" (Triandis, 1980, p. 211),

— *Facilitating Conditions* refers to "objective factors, 'out there' in the environment, that several judges or observers can agree make an act easy to do" (Triandis, 1980, p. 205).

3.3.1.2 Technology acceptance model (TAM)

Technology acceptance model, which was developed for predicting individual adoption and use of new technologies based on TRA by Davis (1989), is the first model that states psychological factors affect technology acceptance (Samaradiwakara & Gunawardena, 2014; Venkatesh & Bala, 2008). According to this model, "perceived usefulness" and "perceived ease of use" are the key determinants of an individual's intention to use the technology, and this intention is the mediator of the actual use. In the technology acceptance model presented in Figure 3.5;

— *Perceived Usefulness* refers to "the prospective user's subjective probability that using a specific application system will increase his or her job performance" (Davis et al., 1989, p. 985)

— *Perceived Ease of Use* refers to "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320).

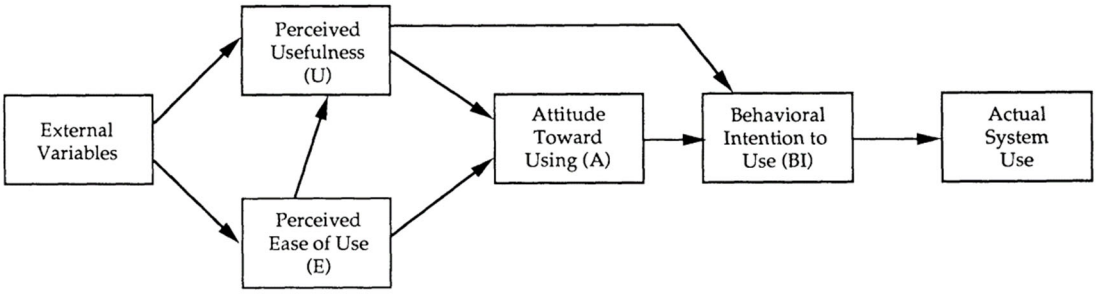


Figure 3.5 : Technology Acceptance Model (TAM), taken from (Davis et al., 1989, p. 985).

3.3.1.3 Combined TAM and TPB (C-TAM-TPB)

This model was developed by combining TAM and TPB (Taylor & Todd, 1995a, 1995b). In this way, "subjective norm" and "perceived behavioral control" from TPB were added to the determinants of TAM (Figure 3.6).

Of these added constructs;

— *Subjective Norm* refers to "the person's perception that most people who are important to him think he should or should not perform the behavior in question" (Fishbein & Ajzen, 1975, p. 302)

— *Perceived Behavior Control* refers to "the perceived ease or difficulty of performing the behavior" (Ajzen, 1991, p. 188).

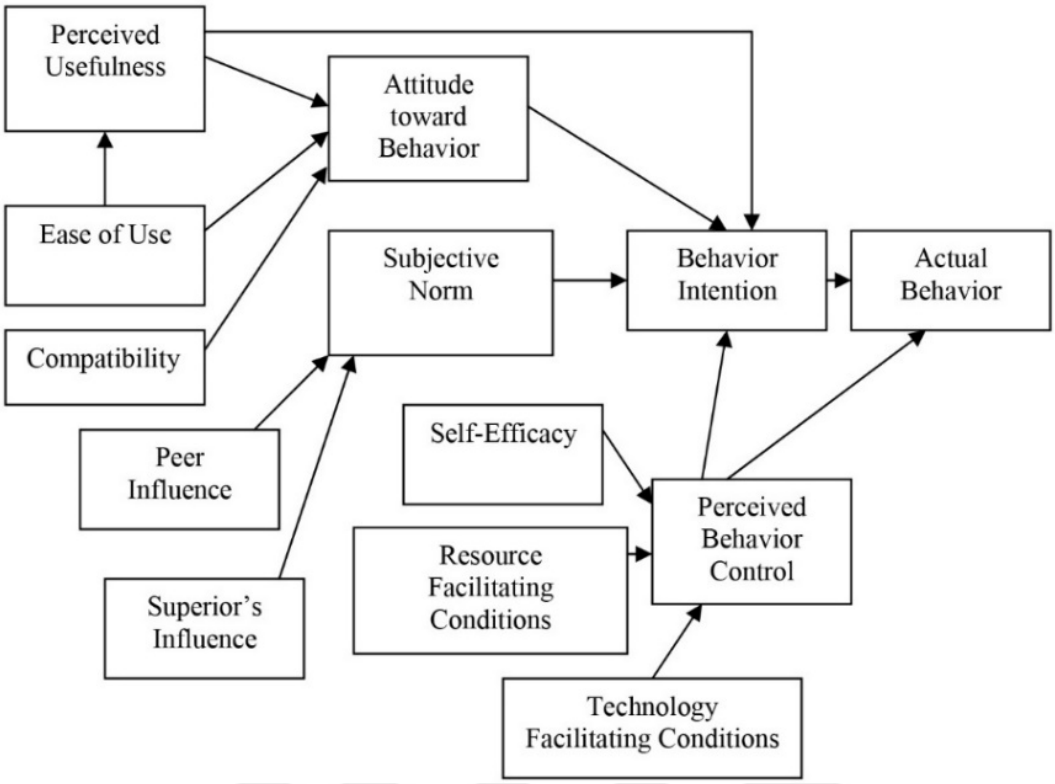


Figure 3.6 : Combined TAM and TPB (C-TAM-TPB), taken from (L. Li, 2010, p. 7).

3.3.1.4 Extended technology acceptance model (TAM2)

This model extends TAM by adding the constructs "image", "job relevance", "output quality", and "result demonstrability" as the determinants of "perceived usefulness" (Venkatesh & Davis, 2000) (Figure 3.7). Of these added constructs;

— *Image* refers to "the degree to which use of an innovation is perceived to enhance one's ... status in one's social system" (Moore & Benbasat, 1991, p. 195),

— *Job Relevance* refers to "an individual's perception regarding the degree to which the target system is applicable to his or her job" (Venkatesh & Davis, 2000, p. 191),

— *Output Quality* refers to the people's consideration of "how well the system performs [the] tasks" (Venkatesh & Davis, 2000, p. 191),

— *Result Demonstrability* refers to "tangibility of the results of using the innovation" (Moore & Benbasat, 1991, p. 203).

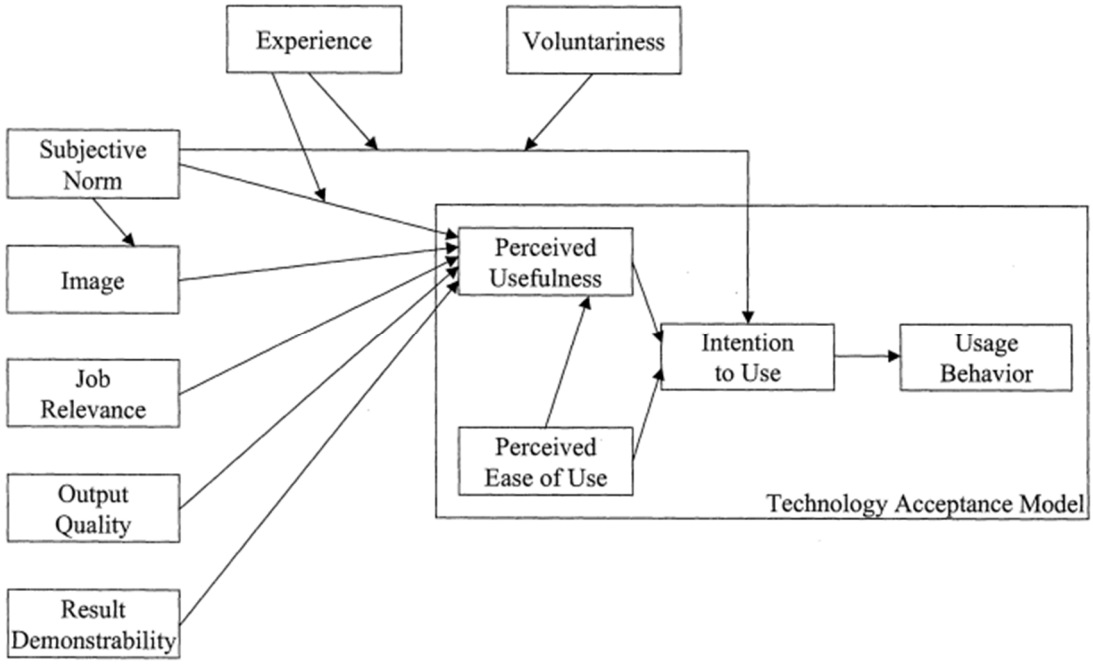


Figure 3.7 : Extended Technology Acceptance Model (TAM2), taken from (Venkatesh & Davis, 2000, p. 188).

3.3.1.5 Technology acceptance model 3 (TAM3)

This model extends TAM2 by adding the constructs "computer self-efficacy", "perceptions of external control", "computer anxiety", "computer playfulness", "percieved enjoyment", and "objective usability" as the determinants of "perceived ease of use" (Venkatesh & Bala, 2008) (Figure 3.8).

Of these added constructs;

— *Computer Self-Efficacy* refers to "the degree to which an individual believes that he or she has the ability to perform a specific task/job using the computer" (Venkatesh & Bala, 2008, p. 279).

— *Perception of External Control* refers to "the degree to which an individual believes that organizational and technical resources exist to support the use of the system" (Venkatesh & Bala, 2008, p. 279).

— *Computer Anxiety* refers to the degree of "an individual's apprehension, or even fear, when she/he is faced with the possibility of using computers" (Venkatesh, 2000, p. 349).

— *Computer Playfulness* refers to "… the degree of cognitive spontaneity in microcomputer interactions" (J. Webster & Martocchio, 1992, p. 204).

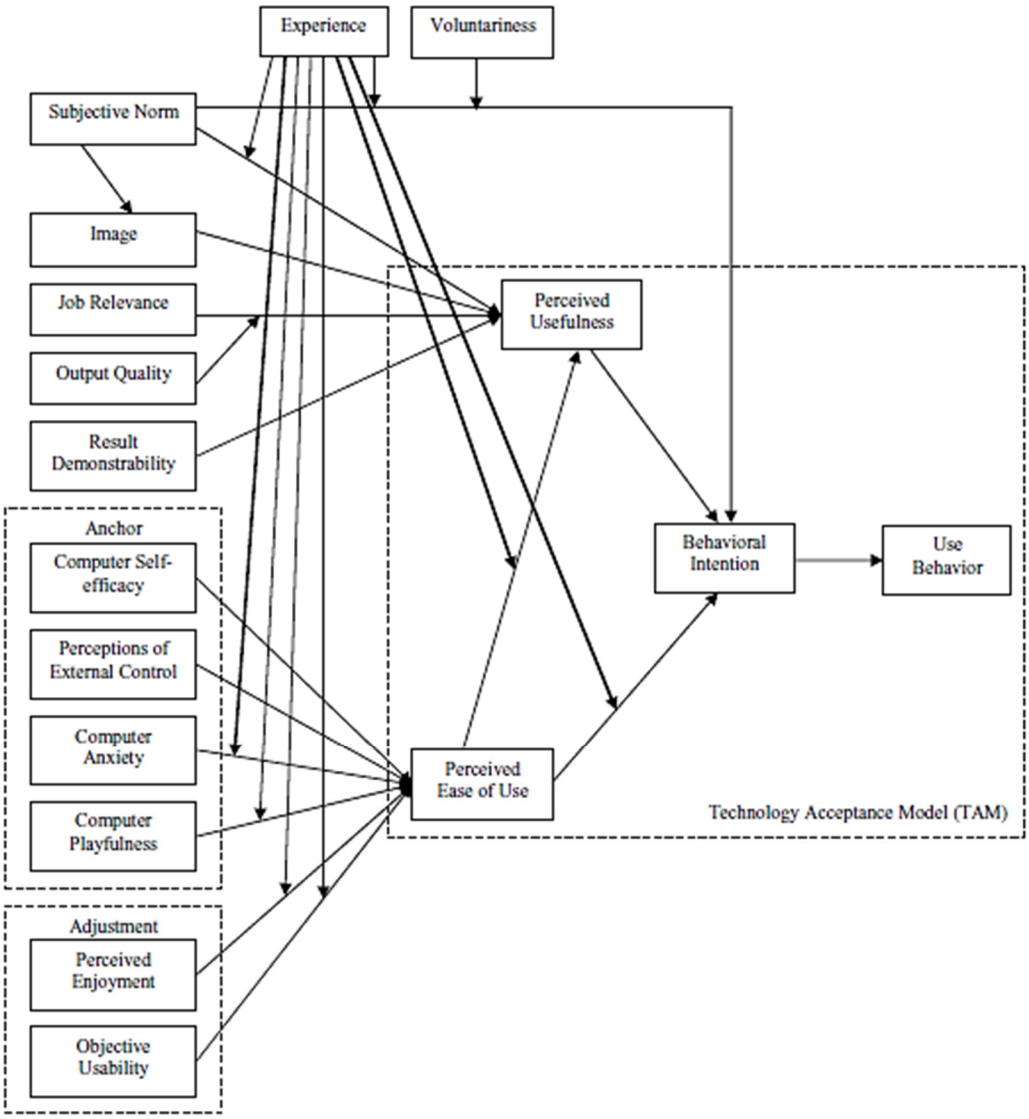


Figure 3.8 : Technology Acceptance Model 3 (TAM3), taken from (Venkatesh & Bala, 2008, p. 280).

— *Perceived Enjoyment* refers to "the extent to which "the activity of using a specific system is perceived to be enjoyable in its own right, aside from any performance consequences resulting from system use" (Venkatesh, 2000, p. 351).

— *Objective Usability* refers to "a comparison of systems based on the actual level (rather than perceptions) of effort required to completing specific tasks" (Venkatesh, 2000, pp. 350–351).

3.3.2 Technology acceptance theories

In this section, well-known technology acceptance theories in the literature are presented with their brief descriptions.

3.3.2.1 Unified theory of acceptance and use of technology (UTAUT)

This theory was developed by Venkatesh et al. (2003) based on four theories (TRA, TPB, SCT, IDT), and four models (MM, MPCU, TAM, C-TAM-TPB) mentioned above. In this theory, as presented in Figure 3.9;

— *Performance Expectancy* refers to "the degree to which an individual believes that using the system will help him/her attain gains in job performance" (Venkatesh et al., 2003, p. 447), and was constructed based on "Perceived Usefulness" of TAM and C-TAM-TPB, "Extrinsic Motivation" of MM, "Job-fit" of MPCU, "Relative Advantage" of IDT, and "Outcome Expectations" of SCT (Venkatesh et al., 2003),

— *Effort Expectancy* refers to "the degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450), and was constructed based on "Perceived Ease of Use" of TAM, "Complexity" of MPCU, "Ease of Use" of IDT (Venkatesh et al., 2003),

— *Social Influence* refers to "the degree to which an individual perceives that important others believes that he or she should use the new system" (Venkatesh et al., 2003, p. 451), and was constructed based on "Subjective Norm" of TRA,TPB, and C-TAM-TPB, "Social Factors" of MPCU and "Image" of IDT (Venkatesh et al., 2003),

— *Facilitating Conditions* refers to "the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system" (Venkatesh et al., 2003, p. 453), and was constructed based on "Perceived Behavioral Control" of TPB and C-TAM-TPB, "Facilitating Conditions" of MPCU and "Compatibility" of IDT (Venkatesh et al., 2003).

Gender, age, experience, and voluntariness of use were evaluated as moderators in this theory.

3.3.2.2 Extended unified theory of acceptance and use of technology (UTAUT2)

This theory extends UTAUT by adding the constructs "hedonic motivation", "price value", and "habit" (Venkatesh et al., 2012) (Figure 3.10). Of these added constructs;

— *Hedonic Motivation* refers to "the fun or pleasure derived from using a technology" (Venkatesh et al., 2012, p. 161),

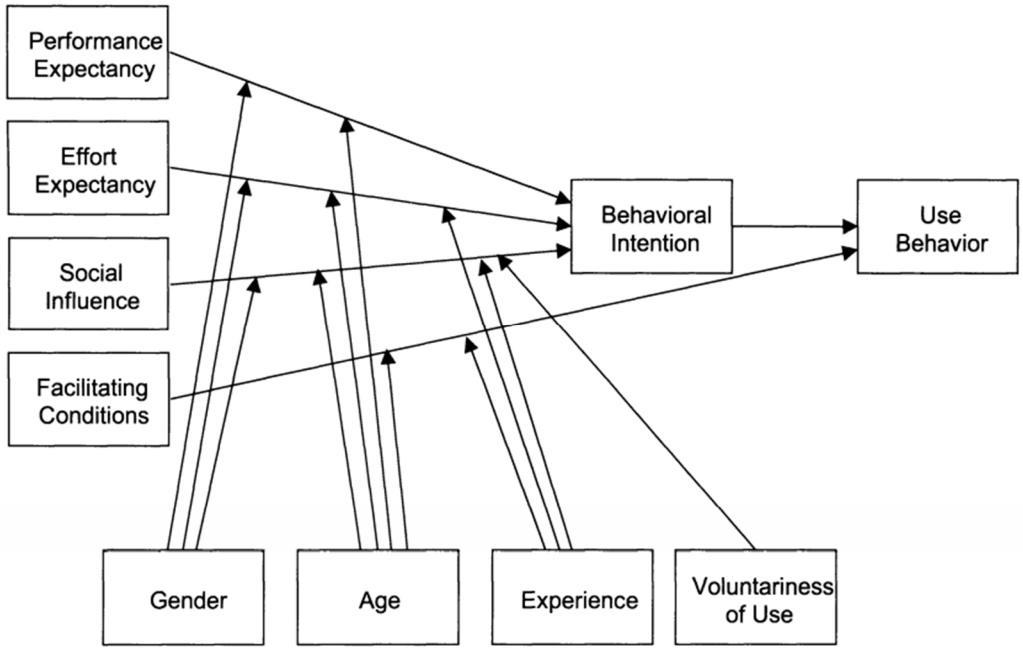


Figure 3.9 : Unified Theory of Acceptance and Use of Technology (UTAUT), taken from (Venkatesh et al., 2003, p. 447).

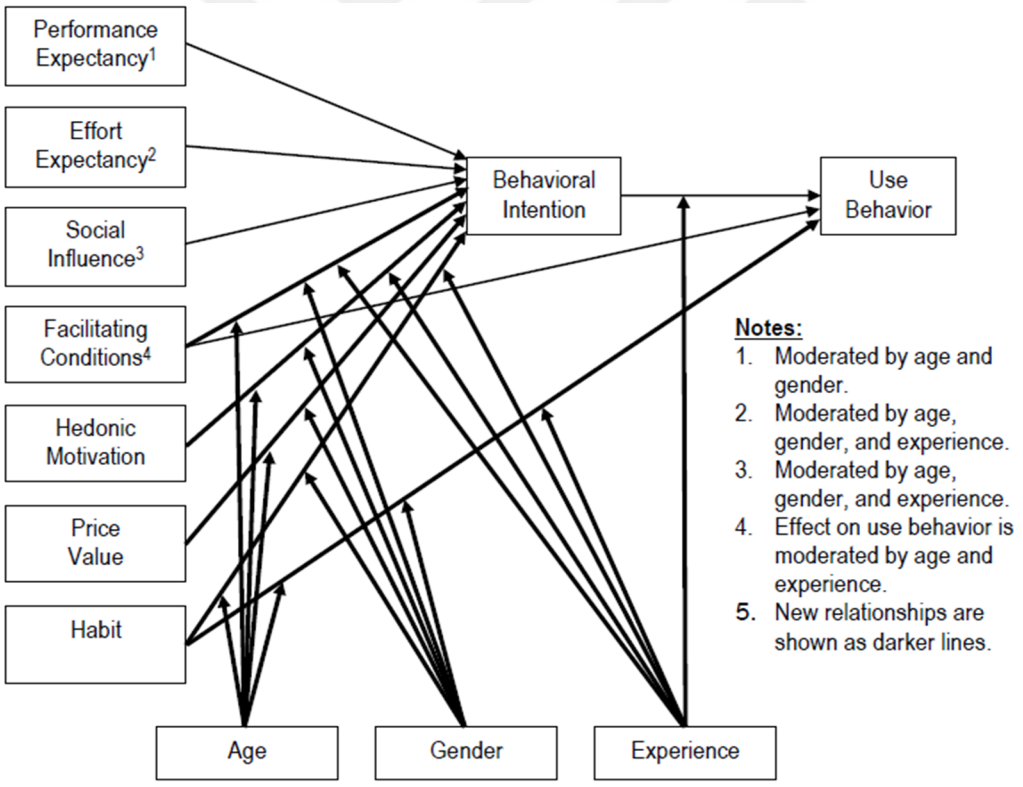


Figure 3.10 : Extended Unified Theory of Acceptance and Use of Technology (UTAUT2), taken from (Venkatesh et al., 2012, p. 160).

— *Price Value* refers to "consumers' cognitive tradeoff between the perceived benefits of the applications and monetary cost for using them" (Venkatesh et al., 2012, p. 161),

— *Habit* refers to "the extent to which people tend to perform behaviors automatically because of learning" (Venkatesh et al., 2012, p. 161).

3.3.3 Comparison of technology acceptance models and theories

There are several studies in the literature conducted for statistically comparing the explanation and the prediction powers of technology acceptance models and theories. These comparisons were made mainly based on R2 value which refers to the model's, or theory's, explanation and prediction power of intention to use. The R2 value is a value between 0 and 1. If this value is close to 1, it means that the model's prediction and explanation powers are high. Table 3.2 presents the R2 values calculated in three much-cited studies (Rondan-Cataluña et al., 2015; Venkatesh et al., 2003, 2012) for the models and theories mentioned above. According to the R2 values in the first column (Venkatesh et al., 2003), UTAUT's value (0.69) is the closest to 1. However, in the other columns, it is seen that UTAUT2's R2 values are closer values to 1 in comparison with UTAUT's R2 values. According to this table, it can be said that UTAUT2 has a better explanation and prediction power for "intention to use" than the other models and theories[5].

Table 3.2 : Comparison of technology acceptance models and theories.

Model/Theory	R2 value for explaining / predicting intention to use		
	Venkatesh et al. (2003)	Rondan-Cataluña et al. (2015)	Venkatesh et al. (2012)
MPCU	0.47	–	–
TAM	–	0.639	–
C-TAM-TPB	0.39	–	–
TAM2	0.53	0.441	–
TAM3	–	0.441	–
UTAUT	0.69	0.441	0.55
UTAUT2	–	0.640	0.73

3.4 Product Acceptance Models

Regarding user's adoption of new technology, another model-based approach in the literature is "product acceptance – system acceptability/acceptance" in Human-

[5] The authors' (Rondan-Cataluña et al., 2015) explanation regarding the low levels of the UTAUT2's R2 value in the column 2: "Chilean mobile users simply use more traditional calls instead of internet services on their mobile devices than other cultures where this technology is more usual and established" (p. 800). This may have caused the low level of the R2 value of "behavioral intention".

Computer Interaction (HCI) field. Shackel's and Nielsen's product acceptance models are the prominent ones in this group. These two models are presented below with their brief descriptions.

3.4.1 Shackel's product acceptance model

Shackel (1991) handles the issue of "product acceptance" with the aspect of consumers' purchase decisions. In his model (Figure 3.11), he incorporates usability into the attributes of the product, and states that consumers/users compare the properties of the products which they plan to acquire, and in a purchase situation, they evaluate the trade-offs between the products' attributes (utility, usability, and likeability) and the costs of them (Keinonen, 1998).

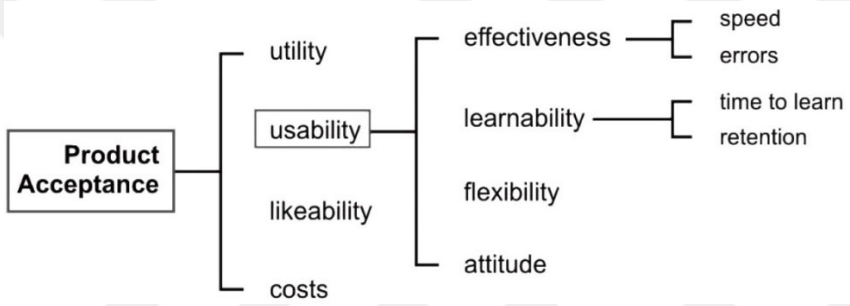


Figure 3.11 : Shackel (1991)'s product acceptance model, taken from (Şimşek, 2008, p. 41).

3.4.2 Nielsen's product acceptance model

According to Nielsen (1993), usefulness is an issue regarding "whether the system can be used to achieve some desired goal" (p. 24), and usability and utility are the determinant factors for the usefulness of a system (Figure 3.12). In Nielsen (1993)'s model, utility refers to "whether the functionality of the system in principle can do what is needed" (p. 25). However, the determinant of "how well users can use that functionality" (p. 25) is usability. So, both the *usefulness* and the *utility level* of a system/product depend on its *usability level*.

On the other hand, a product or technology should, of course, be useful primarily. However, whether it is useful or not can only be understood using it. Therefore, users must be able to use it to accept it as useful (Interaction Design Foundation [IDF], 2016) (Figure 3.13). Dillon & Morris (1996) state that "most HCI researchers assume that the more usable a technology is made, the greater its chances of proving acceptable to

users" (p. 20). For these reasons, it can be said that usability is the key determinant of the system's (product's) acceptability.

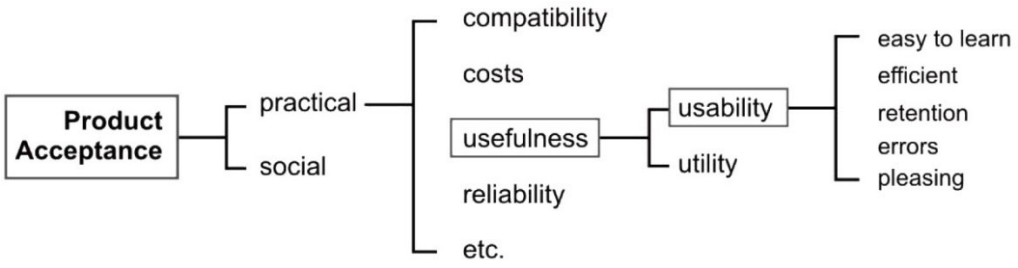


Figure 3.12 : Nielsen (1993)'s product acceptability model, taken from (Şimşek, 2008, p. 42).

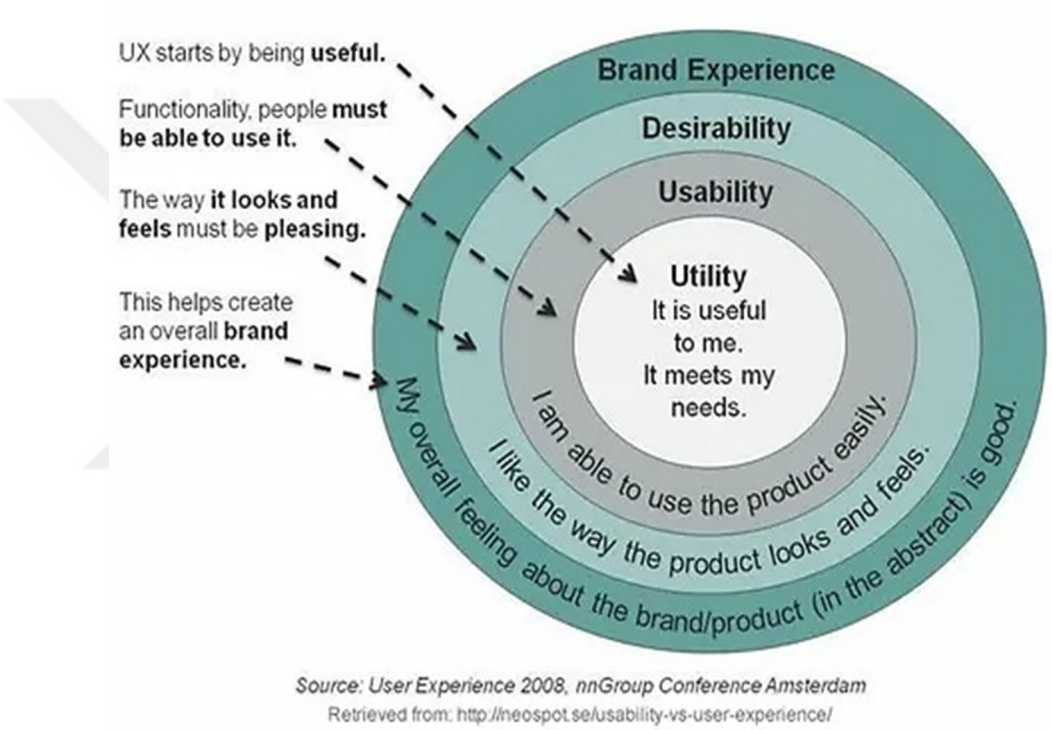


Figure 3.13 : Core components of user experience, taken from (IDF, 2016).

3.5 Summary

The theoretical framework of this study, schematized as in Figure 3.14, can be summarized as follows with the statements that led the research.

— Designing is also an effort to show or present a product that does not yet exist as if it exists,

— Design representations are transmitters conveying industrial design students' design intents,

— The UTAUT2 has a better explanation and prediction power than the other technology acceptance models,

— Usability is the key determinant of the system’s (product's) acceptability.

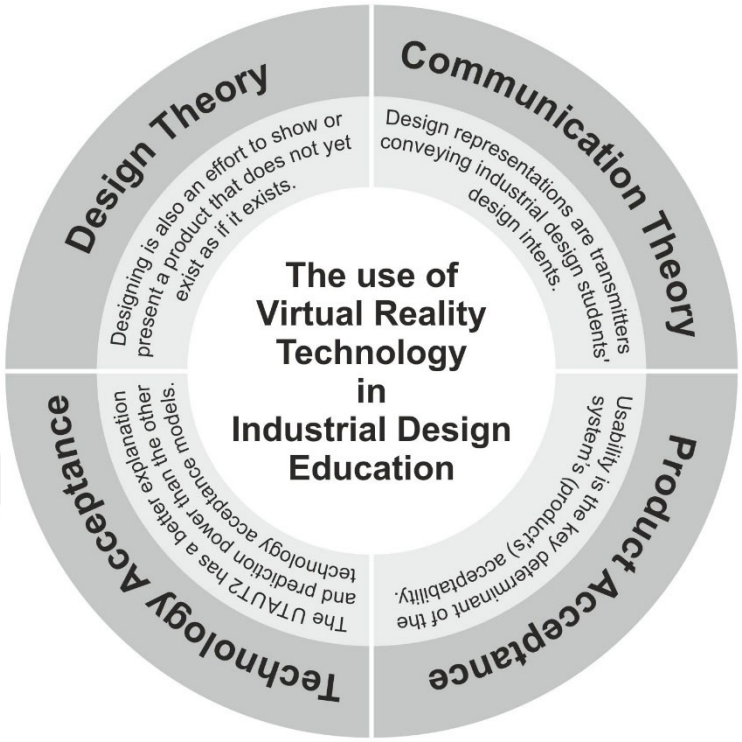


Figure 3.14 : Schematized summary of the theoretical framework of the study.

4. METHODOLOGY

This chapter presents the research design and approach, and the methodological framework of the thesis. Discussions on the validity, reliability, and generalizability of the study are also presented in this chapter. In addition to these, ethical issues regarding the study are clarified.

4.1 Research Design and Approach

Research design is a kind of guide that leads "the investigator in the process of collecting, analyzing, and interpreting" (p. 99) data, and is also considered as "a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation" (Nachmias & Nachmias, 2014, p. 18). However, it should be noted that research design is not only a work plan but also more than that. Main purpose of a research design is "to avoid the situation in which the evidence does not address the research questions" rather than planning research steps (Yin, 2018a, p. 26).

On the other hand, research approach refers to "plans and procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis" (Creswell & Creswell, 2018, p. 334). There are three main research approaches in the literature: (1) "qualitative approach"; (2) "quantitative approach"; and (3) "mixed methods approach".

First of all, qualitative approach is a research approach for exploring and understanding the meaning attributed by individuals or groups to a social or human problem (Creswell & Creswell, 2018). Another feature of qualitative research is that it is a kind of research which "produces findings not arrived at by statistical procedures or other means of quantification" (Strauss & Corbin, 1998, p. 10). Qualitative research conducted related to persons/individuals are generally about people's lives, experiences, opinions, beliefs, behaviors, emotions, and feelings (Strauss & Corbin, 1998).

Secondly, quantitative approach is a research approach for systematic empirical inquiries in which data about observable phenomena is collected, and analyzed by statistical, mathematical, or computational techniques. In quantitative research, collected data, data analysis and results are presented in numerical rather than narrative form (Donmoyer, 2008b). A detailed comparison of quantitative and qualitative research approaches is presented in Table 4.1.

Table 4.1 : A comparison of quantitative and qualitative research approaches, taken from (Leedy & Ormrod, 2016, p. 81).

Question	Quantitative	Qualitative
What is the purpose of the research?	• To explain and predict • To confirm and validate • To test theory	• To describe and explain • To explore and interpret • To build theory
What is the nature of the research process?	• Focused • Known variables • Established guidelines • Preplanned methods • Somewhat context-free • Detached view	• Holistic • Unknown variables • Flexible guidelines • Emergent methods • Context-bound • Personal view
What are the data like, and how are they collected?	• Numerical data • Representative, large sample • Standardized instruments	• Textual and/or image-based data • Informative, small sample • Loosely structured or non-standardized observations and interviews
How are data analyzed to determine their meaning?	• Statistical analysis • Stress on objectivity • Primarily deductive reasoning	• Search for themes and categories • Acknowledgment that analysis is subjective and potentially biased • Primarily inductive reasoning
How are the findings communicated?	• Numbers • Statistics, aggregated data • Formal voice, scientific style	• Words • Narratives, individual quotes • Personal voice, literary style (in some disciplines)

Finally, mixed methods approach is a research approach that involves "collecting both quantitative and qualitative data, integrating the two forms of data" (p. 41), or interpreting together (Creswell & Creswell, 2018). Due to combining the strengths of both quantitative and qualitative approaches, mixed methods approach generates additional insight beyond the information gained either from quantitative or qualitative data, and provides a means to best understand research problems (Creswell, 2008; Creswell & Creswell, 2018).

In accordance with the information presented above, a three-stage research was designed (Figure 4.1). The first stage – *Initial Investigations* – was designed for assessing the existing situation regarding literature, and the thoughts of industrial

design students and instructors (potential user groups) on the use of VR technology in industrial design education before trying the actual use of it. In this stage, two exploratory research was planned with a mixed methods approach:

— A systematic literature review for examining the former attempts regarding the use of VR technology in professional and educational practices of industrial design,

— A preliminary study on the attitudes of potential user groups (industrial design students and instructors) towards the use of VR technology in industrial design studio courses. This preliminary study was constructed on a questionnaire and a group discussion session which is a type of interview. The questionnaire items are based on the items of the extended Unified Theory of Acceptance and Use of Technology (UTAUT2), Single Ease Question (SEQ), and Net Promoter Score (NPS).

These studies are presented in detail in the first section of the next chapter (5.1 First Stage: Initial Investigations).

The second stage – *Integration of Virtual Reality* – was designed with the aim of providing an understanding of how VR technology can be integrated into industrial design education by trying to incorporate the use of it into the studio-based practices of industrial design education under real conditions. In this process, action research was employed by making VR technology available for students and instructors during the studio hours of an industrial design studio course and by making its use mandatory in the jury sessions of the project process of that course. This action research process is presented in detail in the second section of the next chapter (5.2 Second Stage: Integration of Virtual Reality).

The last stage – *Final Investigations* – was designed for assessing the new situation based on the thoughts of students and instructors about the use of VR technology in industrial design studio courses after the actual use of it. For this purpose, a questionnaire-based study and interviews with the user groups were planned with a mixed methods approach. The questionnaire was prepared in the same manner as the first stage. Interviews with instructors were conducted one-to-one, whereas interviews with students were carried out as group interviews with the project groups of the

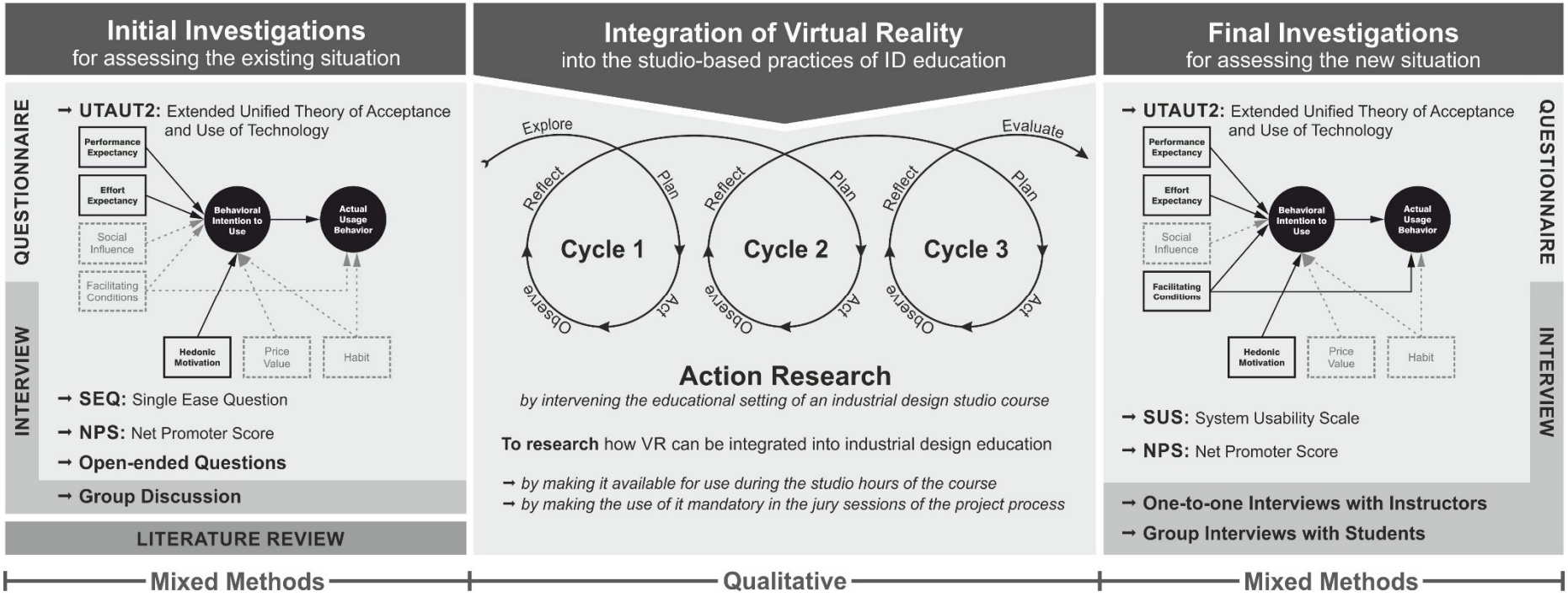


Figure 4.1 : Research design of the study.

students. These studies are presented in the third section of the next chapter (5.3 Third Stage: Final Investigations).

4.2 Methodological Framework

In order to design this thesis study, various research methods and methodologies in the literature are reviewed. Some of them – commonly used ones in the literature – are presented in Table 4.2.

Table 4.2 : Common research method/ologies in alphabetical order.

Method/ology	Brief description	Taken from
Action research	"A type of applied research that focuses on finding a solution to a local problem in a local setting. For example, a teacher might investigate whether a new spelling program she has adopted leads to improvement in her students' achievement scores."	(Leedy & Ormrod, 2016, p. 84)
Case study	"A type of qualitative research in which in-depth data are gathered relative to a single individual, program, or event for the purpose of learning more about an unknown or poorly understood situation."	
Correlational research	"A statistical investigation of the relationship between two or more variables. Correlational research looks at surface relationships but does not necessarily probe for causal reasons underlying them."	
Design-based research	"A multistep, iterative study in which certain instructional strategies or technologies are implemented, evaluated, and modified to determine possible factors influencing learning or performance."	
Developmental research	"An observational-descriptive type of research that either compares people in different age groups (a cross-sectional study) or follows a particular group over a lengthy period of time (a longitudinal study)."	
Ethnography	"A type of qualitative inquiry that involves an in-depth study of an intact cultural group in a natural setting."	
Experimental research	"A study in which participants are randomly assigned to groups that undergo various researcher-imposed treatments or interventions, followed by observations or measurements to assess the effects of the treatments."	
Ex post facto research	"An approach in which one looks at conditions that have already occurred and then collects data to investigate a possible relationship between these conditions and subsequent characteristics or behaviors."	
Grounded theory	"A type of qualitative research aimed at deriving theory through the use of multiple stages of data collection and interpretation."	
Interview	A qualitative method "to explore the outlook, understanding, and perspective of individuals on the problem under research".	(Nagmode, 2019, p. 36)
Literature Review	A type of research designed to examine "the results of other studies that are closely related to the one being undertaken".	(Creswell & Creswell, 2018, p. 66)
Observation Study	A type of research "in which a particular aspect of behavior is observed systematically and with as much objectivity as possible."	(Leedy & Ormrod, 2016, p. 84)
Phenomenological research	"A qualitative method that attempts to understand participants' perspectives and views of physical or social realities."	
Quasi-experimental research	"A method similar to experimental research but without random assignment to groups."	
Survey research	A type of research used "to identify characteristics of a given population—people's attitudes, beliefs, goals, behaviors, preferences, opinions—by asking them questions".	(Rosen, 2019, p. 103)

Based on the review summarized in Table 4.2, it is decided to employ action research methodology to research how VR technology can be integrated into industrial design education as it is a methodology frequently employed "to understand the effects of implementing a new initiative or technology where one is uncertain how effective it might be" (Schadewitz & Zamenopoulos, 2009, p. 201) in studies about "the introduction of information and communication technologies into educational settings" (Somekh, 2006, p. 2). In line with Schadewitz and Zamenopoulos (2009) and Somekh (2006), this research focuses on the introduction of VR technology whose effects on industrial design education have not been clear enough yet into the educational setting of industrial design studio courses.

On the other hand, action research is a methodology that was first conceptualized by Lewin (1946) as a research process consists of the cycles of "planning", "acting", "observing", and "reflecting" (Figure 4.2). Archer (1995) describes it as a "systematic investigation through practical action calculated to devise or test new information, ideas, forms or procedures and to produce communicable knowledge" (p. 6). According to Avison et al. (1999), action research "combines theory and practice (and researchers and practitioners) through change and reflection in an immediate problematic situation within a mutually acceptable ethical framework" (p. 94), and it is "an iterative process involving researchers and practitioners acting together on a particular cycle of activities, including problem diagnosis, action intervention, and reflective learning" (p. 94). Somekh (2006) defines action research as "a means whereby research can become a systematic intervention, going beyond describing, analyzing and theorizing social practices to working in partnership with participants to reconstruct and transform those practices" (p. 1).

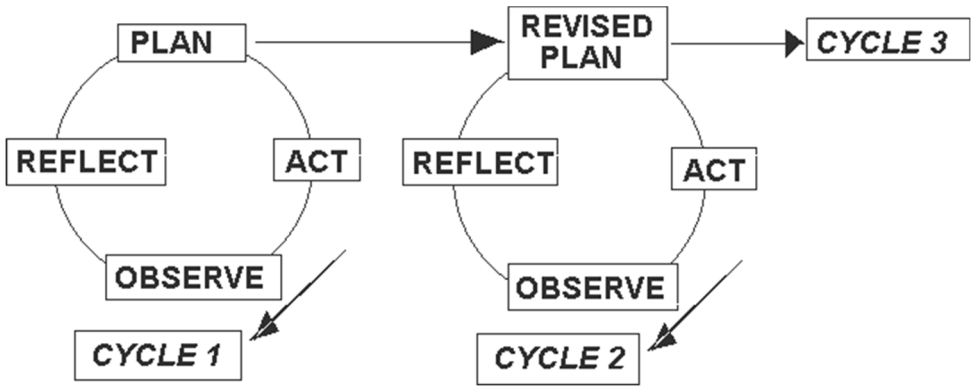


Figure 4.2 : The generic process of action research, taken from (Riding et al., 1995).

All in all, action research is a cyclic process that involves "planning a change, acting and then observing what happens following the change, reflecting on these processes and consequences, and then planning further action" (Robson, 2002, p. 217), and as a consequence of its this characteristic, regarding the action research methodology, one of the most asked questions is "How many cycles are enough?". However, according to Atkins and Wallace (2012), such a question is the reflection of a mindset that reduces action research to a *procedure*. They highlight that McTaggart (1996), as well, has warned against the thinking of following a spiral that necessarily constitutes action research. According to McTaggart (1996), "action research is not a 'method' or a 'procedure' for research but a series of commitments to observe and problematize through practice a series of principles for conducting social enquiry" (p. 249). Based on this conception, Atkins and Wallace (2012) state that "for action research practitioners, who are committed to continually developing educational practice in a socially active context, observations and reflections on particular situations are ongoing and never-ending" (p. 134). In other words, the knowledge revealed during and at the end of the cyclic process of action research is important, not the cycle count. And, the reached point at the end of the last cycle of an action research study can be considered as the starting point of the first cycle of another action research study to be conducted further. For these reasons, when designing this research, the focus was not on how many cycles the action research process would consist of but rather on the research process itself.

On the other hand, the action research process in this thesis is constructed mainly based on user research. According to Rohrer (2014), all types of user research is based on data collected with qualitative and/or quantitative approaches by focusing on either what people do (refers to behaviors of people), or, what people say (refers to attitudes of people). With this point of view, he states that user research methods can be distributed according to data collecting approaches and their question types to be answered by research methods in a 2D framework with the axes of "Attitudinal – Behavioral" and "Qualitative – Quantitative". In line with the research question of this study, the focused areas on Rohrer's user research landscape when designing the research are depicted with hatching in Figure 4.3. However, in the selection of the methods to be used in the research, it was taken into consideration not only the methods

shown in this landscape but also the ones that are not shown such as group discussion method.

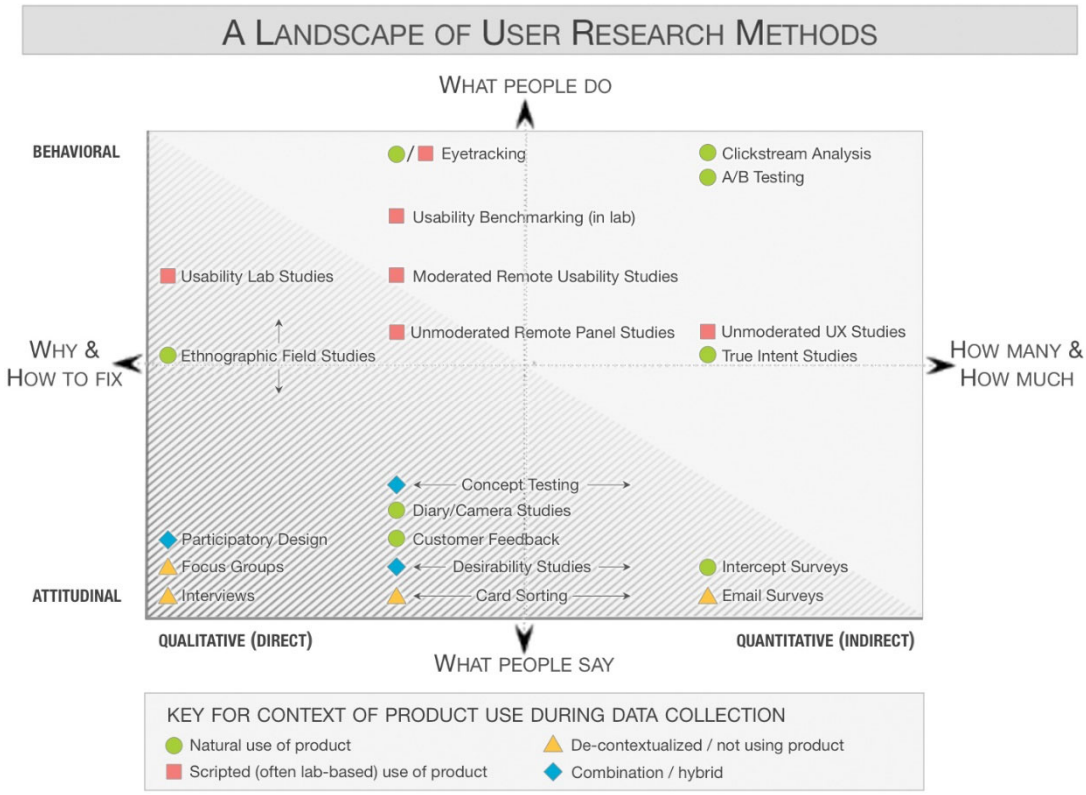


Figure 4.3 : Methodological framework of the research, prepared based on Rohrer's (2014) "Landscape of User Research Methods" and his figure of "Questions Answered by Research Methods across the Landscape".

To sum up, it can be said that this research is an action research mainly based on attitudinal data gathered with a qualitative approach. However, it is supported, where relevant, by either behavioral, or quantitative data, as well. The methods selected to collect and analyze data in each particular study are presented in Table 4.3 and discussed along with the reasons for their selection in the sections where these studies are presented.

4.3 Validity, Reliability, and Generalizability of The Study

Whether the criteria of validity, reliability, and generalizability which are applicable for quantitative research are also applicable for qualitative research is one of the most controversial topics (Bryman & Teevan, 2005; Cifter, 2011; Potter, 2000; Robson, 2002). Although some qualitative researchers claim that these criteria cannot apply to qualitative research, it is obvious that there is high need for some kind of quality check

Table 4.3 : Summary table of the methods used in the study.

Phase	Aim	Methodology	Data Collection Method	Data Analysis Method
Initial Investigations	To examine the former works in the literature regarding the use of VR in industrial design practice and education.	Literature Review	Systematic Literature Review	Descriptive Statistics, Quantitative & Qualitative Content Analysis
	To reveal the initial assessments of industrial design students and instructors about the use of VR technology in industrial design education.	Survey	Questionnaire	Descriptive Statistics
		Interview	Group Discussion	Quantitative & Qualitative Content Analysis
Integration of Virtual Reality	To research how VR can be integrated into industrial design education.	Action Research	Observation, One-to-one & Group Interview	Qualitative Content Analysis
Final Investigations	To reveal the final assessments of students and instructors after the actual use of VR.	Survey	Questionnaire	Descriptive Statistics
		Interview	One-to-one & Group Interview	Quantitative & Qualitative Content Analysis

or measure for qualitative research as well. For this reason, on one hand, some qualitative researchers have generated their own concepts of validity, reliability, and generalizability. On the other hand, some have developed alternative terminologies associated with these criteria for qualitative research (Golafshani, 2003; Noble & Smith, 2015) (Table 4.4). Therefore, in this section, the validity, reliability, and generalizability of this thesis study are discussed, taking into consideration the literature on qualitative research.

Table 4.4 : Validity, reliability and generalizability in qualitative research and alternative terminologies associated with them, taken from (Noble & Smith, 2015, p. 34).

Quantitative research terminology and its application to qualitative research (Long & Johnson, 2000)	**Alternative terminology associated with credibility of qualitative research (Lincoln & Guba, 1985)**
Validity The precision in which the findings accurately reflect the data	**Truth value** Recognizes that multiple realities exist; the researchers' outline personal experiences and viewpoints that may have resulted in methodological bias; clearly and accurately presents participants' perspectives
Reliability The consistency of the analytical procedures, including accounting for personal and research method biases that may have influenced the findings	**Consistency** Relates to the 'trustworthiness' by which the methods have been undertaken and is dependent on the researcher maintaining a 'decision-trail'; that is, the researcher's decisions are clear and transparent. Ultimately an independent researcher should be able to arrive at similar or comparable findings. **Neutrality (or confirmability)** Achieved when truth value, consistency and applicability have been addressed. Centers on acknowledging the complexity of prolonged engagement with participants and that the methods undertaken and findings are intrinsically linked to the researchers' philosophical position, experiences and perspectives. These should be accounted for and differentiated from participants' accounts
Generalizability The transferability of the findings to other settings and applicability in other contexts	**Applicability** Consideration is given to whether findings can be applied to other contexts, settings or groups

4.3.1 Validity of the study

According to Leung (2015), "validity in qualitative research means 'appropriateness' of the tools, processes, and data" (p. 325), and the challenge in assessment of the validity of qualitative research is related to the ontological and the epistemological standpoints of that research. He exemplifies this situation as follows:

> The concept of 'individual' is seen differently between humanistic and positive psychologists due to differing philosophical perspectives: Where humanistic psychologists believe "individual" is a product of existential awareness and social interaction, positive psychologists think the 'individual' exists side-by-side with formation of any human being. Set off in different pathways, qualitative research regarding the individual's wellbeing will be concluded with varying validity. (Leung, 2015, p. 325)

The main determinant that will guide the discussion regarding the validity of this thesis study is its epistemological standpoint. There are two primary theoretical perspectives in social research: positivism and interpretivism. The major differences between these two approaches are presented in Table 4.5.

Table 4.5 : The major differences between positivism and interpretivism, taken from (Henn et al., 2006, p. 16).

Positivism	**Interpretivism**
1. Knowledge is based on phenomena that is directly observable (phenomenalism)	1. Knowledge is based on understanding interpretations and meanings that are not directly observable
2. The social world should be researched using the principles of natural science (such as experiments). Such a shared approach is often referred to as the unity of scientific method	2. The social world should be studied in its natural state (using participant observation and depth interviews) to understand naturally occurring behavior
3. There is a stress on reliability and generalizability	3. There is a stress on validity
4. Explanation is achieved through the formulation of causal laws or law-like generalizations (nomothetic approach)	4. Explanation is achieved through descriptions of social meanings/reasons and other dispositions to action (idiographic approach)
5. There is use of the hypothetico-deductive method in which there is an emphasis on testing given theory	5. There is use of the analytic-inductive method in which theory is generated from the data
6. Methods imply researcher/respondent detachment in the objective collection of data	6. Methods imply insider approach - participation in life and culture of respondent/closeness of respondent and researcher in the joint construction of subjective data
7. Analysis is based on the statistical testing of given theories	7. Analysis is based on verbal, action, and situation description from which theory evolves

This research

— is a *social research* because both the preliminary study and the main study in this thesis involve the investigation of the attitudes of human beings;

— involves understanding the interpretations and the meanings that are not directly observable;

— has a *theory-building (inductive) approach* in which theory is generated from the data mainly derived from the analysis of the thoughts of the participants;

— was carried out in the natural environments of participants and under real conditions.

Therefore, the epistemological standpoint of this research is interpretivism. Hence, the main concern in this thesis is concentrated on the validity of the research. There are three principal threats for validity in qualitative studies: *reactivity*, *researcher bias*, and *respondent bias* (Lincoln & Guba, 1985; Padgett, 2016; Robson, 2002). The descriptions of these threats are presented in Table 4.6. There are also some strategies developed for dealing with these threats in the literature. Of these strategies, commonly used ones are presented with their brief descriptions in Table 4.7, whereas their effects on these threats – reactivity, researcher bias, and respondent bias – are presented in Table 4.8. In this thesis, to ensure validity, the strategies "prolonged involvement, data triangulation, methodological triangulation, theory triangulation, peer debriefing, negative case analysis, and audit trail" were employed as much as possible. The strategies of 'observer triangulation' and 'member checking' could not be employed.

4.3.2 Reliability of the study

Middleton (2021) defines reliability as "the extent to which the results can be reproduced when the research is repeated under the same conditions". However, according to Stenbacka (2001), these kinds of classical definitions "stem from experimental-psychological traditions, where researcher and method are seen as separated from each other" (p. 552). In qualitative research, it is not possible to separate the researcher and the method. Moreover, in qualitative research, there are lots of variables affecting the participant(s), the researcher(s), and the study setting(s) (Cifter, 2011). Therefore, in qualitative research, it is often not possible to reproduce the research under exactly the same conditions. From this point of view, "reliability has no relevance in qualitative research" (Stenbacka, 2001, p. 552).

On the other hand, according to Perakyla (2004), in a research conducted with a qualitative approach mainly based on recordings and transcriptions, "the key aspects of reliability involve *selection of what is recorded, the technical quality of recordings*

Table 4.6 : Descriptions of three common threats on validity in qualitative research, taken from (Kriukow, 2020).

Threat	Description
Reactivity	a possible influence of the researcher himself/herself on the studied situation and people
Researcher bias	any kind of negative influence of the researcher's knowledge, or assumptions, of the study, including the influence of his or her assumptions of the design, analysis or, even, sampling strategy
Respondent bias	a situation where respondents do not provide honest responses for any reason, which may include them perceiving a given topic as a threat, or them being willing to 'please' the researcher with responses they believe are desirable

Table 4.7 : Commonly used strategies to deal with threats on validity and their brief descriptions.

Strategy	Description
Prolonged involvement	To spend a long time with participants in the research setting or the natural flow of life (Kriukow, 2020; Lundy, 2008; Robson & McCartan, 2016)
Triangulation	— Data triangulation: to use more than one method for data collection such as observation, interviews, documents — Observer triangulation: to employ more than one observer in the study — Methodological triangulation: to use mixed method approach combining quantitative and qualitative approaches — Theory triangulation: to be based on multiple theories or perspectives (Denzin, 1988; Robson & McCartan, 2016)
Peer debriefing	To review and discuss the researcher's thinking regarding all or parts of the research process with peers who are not involved in the study (Nguyen, 2008)
Member check(ing)	To check the transcriptions, interpretations, analysis made by the researcher, and/or the emerged findings of the study with the participants (Kriukow, 2020; Robson & McCartan, 2016; Sandelowski, 2008)
Negative case analysis	To analyze the cases (or data sets obtained from a single participant) that do not fit the patterns that emerged from the rest of the data (Brodsky, 2008; Kriukow, 2020)
Audit trail	To keep a full record of all research-related activities throughout the study (Kriukow, 2020; Robson & McCartan, 2016)

Table 4.8 : The effects of the strategies to deal with the threats on reactivity, researcher and respondent biases, taken from (Kriukow, 2020).

	Reactivity	Researcher bias	Respondent bias
Prolonged involvement	Reduces threat	Increases threat	Reduces threat
Triangulation	Reduces threat	Reduces threat	Reduces threat
Peer debriefing	No effect	Reduces threat	No effect
Member checking	Reduces threat	Reduces threat	Reduces threat
Negative case analysis	No effect	Reduces threat	No effect
Audit trail	No effect	Reduces threat	No effect

and *the adequacy of transcripts*" (p. 288). For this reason, to improve the reliability of the findings, special attention has been paid to the quality of the recordings and the adequacy of the transcriptions throughout this study.

On the other hand, according to Perakyla (2004), in a research conducted with a qualitative approach mainly based on recordings and transcriptions, "the key aspects of reliability involve *selection of what is recorded, the technical quality of recordings* and *the adequacy of transcripts*" (p. 288). For this reason, to improve the reliability of the findings, special attention has been paid to the quality of the recordings and the adequacy of the transcriptions throughout this study.

4.3.3 Generalizability of the study

Generalizability which is "a synonym for external validity" (Donmoyer, 2008a) is defined by the American Psychological Association (APA, 2020) as "the extent to which results or findings obtained from a sample are applicable to a broader population". In other words, it refers to whether the achieved results derived from a sample stand for the entire population. According to Stenbacka (2001), defining generalizability in this way "puts pressure on the sample to be representative for the whole population being researched" (p. 552) and "makes qualitative research look suspicious" (p. 552) due to its small sample size. For this reason, Yin defines two types of generalization: (1) *statistical generalization*, based on "the logic whereby the findings from a sample are claimed to apply to its universe, usually involving some statistical inference" (2018a, p. 288); and (2) *analytic generalization,* that "consists of a carefully posed theoretical statement, theory, or theoretical proposition" (2018b, p. 1). According to him, analytic generalization "can take the form of a lesson learned, working hypothesis, or other principle that is believed to be applicable to other situations" (Yin, 2018b, p. 1).

Being applicable to other situations refers to "transferability" which is defined by Trochim (2020) as "the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings". Jensen (2008) states that there are two strategies commonly used to increase the transferability of qualitative research: *thick description* and *purposeful (purposive) sampling*. He describes 'thick description' as giving "a full and purposeful account of the context, participants, and research design" (p. 886) to the reader, and 'purposeful (purposive) sampling' as

selecting the participants who "most represent the research design, limitations, and delimitations of the study" (p. 886). Accordingly, to increase the transferability of the research findings of this thesis, why the methods used to collect data were chosen and how they were applied during the research process, how the sample was selected, how the collected data were analyzed, and the achieved results were presented comprehensively within the relevant chapters.

4.4 Ethical Issues

The research conducted within this thesis study has been not only approved by the Istanbul Technical University (ITU) Humanities and Social Sciences Committee of Human Research Ethics but also by the ITU Health and Engineering Sciences Human Research Ethics Committee on 28/02/2018. These approvals are presented in Appendix D[6]. Also, before their active participation in the in-studio study, the Informed Consent Form (ICF) prepared for this study was handed out to participants, and they were informed about they were free to withdraw from the study at any time without declaring any reason. Besides, at the end of the in-studio study, the participants signed a consent form regarding the use of any kind of personal data (visual, audio, written, etc.) obtained from them throughout the study. This consent form is presented in Appendix C.

[6] The title of the thesis has been changed later.

5. PROCEDURES, METHODS AND FINDINGS OF THE RESEARCH

As explained in the previous chapter, a three-stage research was conducted within this thesis. This chapter presents the procedures followed and the findings for each stage.

5.1 First Stage: Initial Investigations

Before the in-studio study, two exploratory studies were conducted for assessing the existing situation: (1) a *systematic literature review* on the former works regarding the use of VR in industrial design practice and education; and (2) a *preliminary study* on the attitudes of industrial design students and instructors towards the use of VR technology in industrial design studio courses. With these initial investigations, it was aimed to find answers to the questions:

- What are the former studies regarding the use of VR technology in industrial design education? What do these studies say?
- What are the opinions of industrial design students and instructors about the use of VR technology in industrial design education?

This section presents the procedures followed, methods used, and results achieved in these investigations.

5.1.1 Systematic literature review on related works[7]

As the first exploratory study, a systematic literature review was done to examine the initial attempts regarding the use of VR in practice and education of industrial design.

This literature review was limited to articles and proceedings that;

- were published in English,

[7] This literature review is revised later by extending to 2020. The extended version was published in the article entitled "An overview of virtual reality within industrial design education" (doi: 10.1108/JEDT-02-2020-0048). Also, the revised versions of the tables and figures presented in this section can be seen in Appendix A.

— were indexed up to 2018 in the databases of Scopus and Web of Science collections,

— involved the phrases “industrial design” and “virtual reality” in their titles, abstracts, or keywords[8].

As mentioned before, practices in profession and education of industrial design cannot be considered separately from each other. For this reason, literature review was intentionally done with the keywords “industrial design” and “virtual reality” instead of “industrial design education” and “virtual reality”.

The search done in all databases of Scopus and Web of Science returned respectively 122 and 83 document results. The document count was reduced in 146 by merging the duplicate results into a single result. After that, by reading one-by-one, 33 studies regarding industrial design practices conducted by using VR were detected. In this selection process, those papers which contain the search keywords just as generic words, and those studies whose aims and procedures were not well-described were excluded. As a result of the analysis of selected papers, it was seen that the studies can be categorized under two main groups:

— *VR-focused studies*: those done with the motivation of improving VR technology to make it usable for industrial designers (a total of 20 papers)

— *ID-focused studies*: those done with the motivation of attempting to use VR technology in industrial design practice and education (a total of 13 papers)

Classified distribution of these studies by years is presented in Figure 5.1.

On the other hand, it was found out that 10 out of 13 ID-focused studies were carried out by concentrating on the professional practice of industrial design, whereas 3 were conducted by focusing on the educational practice of it. Classified distribution of ID-focused studies by year according to this differentiation is presented in Figure 5.2.

As a result of the review of VR-focused studies, it was observed that VR technology was considered primarily as a modelling and visualization tool for industrial design, and its abilities regarding these issues were tried to be improved (Figure 5.3). On the other hand, the analysis of the professional practice- related studies showed that VR

[8] Similar keywords such as “product design” and “simulation” were automatically covered by the search engines of Scopus and Web of Science databases.

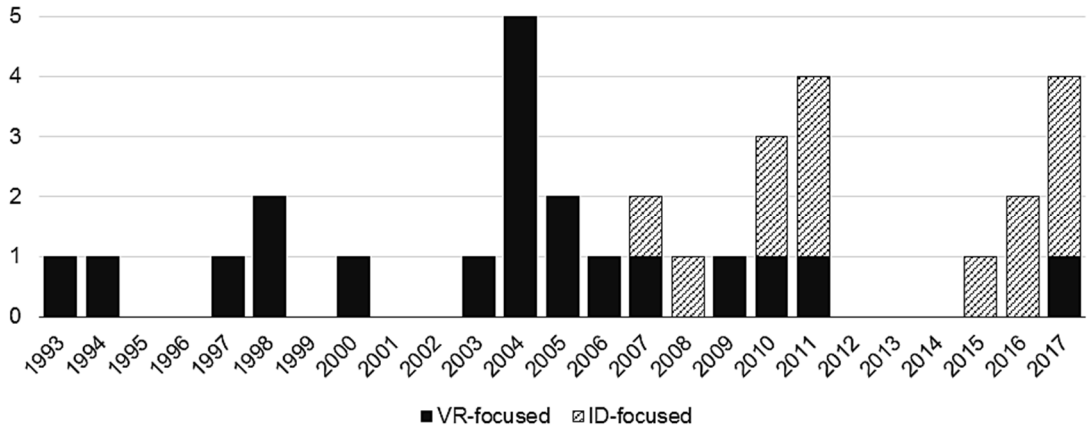


Figure 5.1 : The stacked column chart of the selected studies by years.

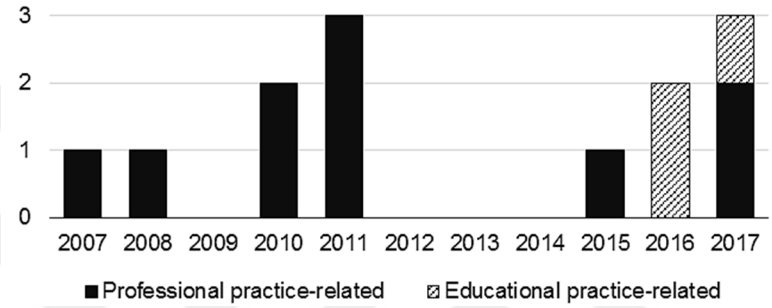


Figure 5.2 : The stacked column chart of the ID-focused studies by years.

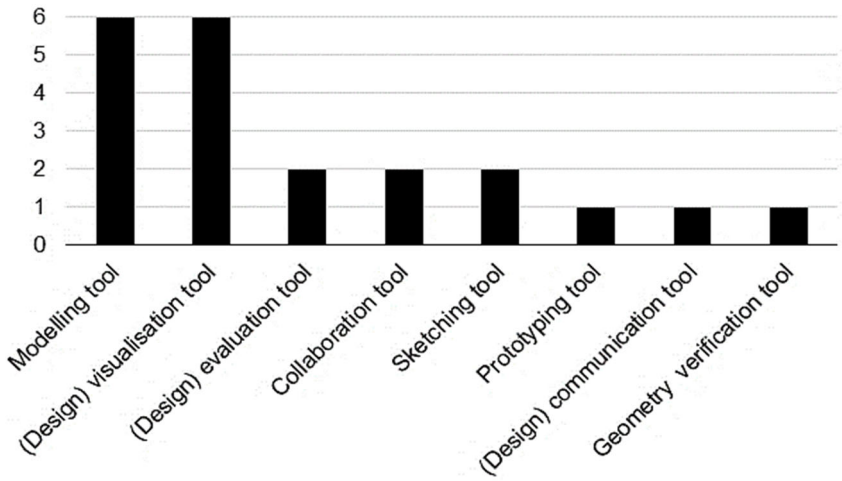


Figure 5.3 : Types of handling of VR in VR-focused studies.

technology was tried to be used in the professional practices of industrial design as: a usability evaluation tool; an ergonomic evaluation tool; a visualization tool; a product demonstration/presentation tool; an interactive prototyping tool; an immersive mood board; a sketching tool; and a collaboration tool (Table 5.1). If these results are interpreted in association with the production of design representations in the industrial design process, it can be said that, so far, VR technology has been tried to employ

— as *an inspirational material* before the creation of design representations,

— as *a sketching, modelling, prototyping and visualization tool* in creating design representations,

— as *a presentation, demonstration, experiencing, usability evaluation and ergonomic evaluation tool* after the creation of design representations,

— as *a collaboration tool* in and after the creation of design representations

in industrial design practice.

Table 5.1 : VR use types in professional practice-related studies.

VR used as a(n)	Bruno et al. (2007)	Mengoni et al. (2008)	Meijer et al. (2010)	Zhikai & Yingying (2010)	Ma et al. (2011)	Bordegoni et al. (2011)	Zhou et al. (2011)	Rieuf et al. (2015)	Rieuf et al. (2017)	Clergeaud et al. (2017)
usability evaluation tool	■									
ergonomic evaluation tool		■			■					
visualization tool			■							
product demonstration tool				■						
interactive prototyping tool						■	■			
immersive mood board								■	■	
sketching tool										
collaboration tool										■

Detected studies of VR use in educational practices of industrial design are presented in Table 5.2 with their industrial design education (IDE) related aims. According to this table, preliminary questions asked regarding the use of VR in industrial design education in the literature are:

— How should the ideal design-oriented VR system be for the use of industrial design students? (Liang et al., 2016)

— How can VR be used methodologically in industrial design education? (Jimeno-Morenilla et al., 2016)

— How can students enhance their presentations and enrich the delivery of design information by immersive 3D visualizations? (Camba et al., 2017)

Table 5.2 : The studies related to the use of VR technology in industrial design education.

Reference	Title	IDE-related Aim(s)
Liang et al. (2016)	A study on design-oriented demands of VR via ZMET-QFD model for industrial design education and students' learning	To analyze and comprehend the ideal design-oriented VR system for industrial design students; to generalize the industrial students' VR demands
Jimeno-Morenilla et al. (2016)	Using virtual reality for industrial design learning: a methodological proposal	To develop a methodology that enables not only learning different design techniques, but also, assessing the creativity skills of students in industrial design engineering courses.
Camba et al. (2017)	Immersive visualization technologies to facilitate multidisciplinary design education	To get students to investigate how immersive 3D visualizations can enrich the delivery of design information; to get them to enhance presentations and simulations in their respective fields

The conclusions of these studies are summarized as follows.

Liang et al. (2016) state that,

— the operation of a visual interface of VR should be similar to *students' manner of thinking*,

— VR should allow students to *work intuitively*,

— VR should be a *packaged program*, and should have a database to *reduce operational faults* and to *enhance efficiency*,

— VR should have *guidelines* and *warnings*, especially for wide applications.

Jimeno-Morenilla et al. (2016) claim that it is possible not only to employ VR in learning different design techniques but also to *assess the creativity skills* of students even in these cases in which VR is employed.

Camba et al. (2017) state that VR enriches the *delivery of students' design information*.

However, among these studies, the one by Jimeno-Morenilla et al. (2016) is purely theoretical, and others have not been conducted by the systemized and structured actual-use of VR technology in the real setting of a design studio course.

5.1.2 Preliminary study[9]

As mentioned before, the aim of the study is to find out ways for integrating VR (VR) technology into the studio-based practices of industrial design education. However, there is a lack of research in the literature regarding the attitudes and/or the behavioral intentions of industrial design students and instructors, who are the main actors of industrial design education, towards the use of VR technology in industrial design studio courses. In a study to be conducted without researching whether they have such an intention, data could have been collected from unwilling users by forcing them to use VR technology. Such a situation is one that may affect the results of such a study. Moreover, users may have some pre-judgments about novel technologies such as finding it complicated to use, or supposing it being not so beneficial for some cases. This is another factor determining the mood of potential users in actual use scenarios. For this reason, to collect the attitudinal data from potential user groups, an exploratory study was conducted as a preliminary study, focusing on the opinions of industrial design students and instructors about the use of VR technology in industrial design studio courses before the actual use of it under real conditions.

5.1.2.1 Procedure and method

For this preliminary study, all industrial design departments in Turkey (a total of 26 universities for the date of the study) were sent an invitation letter for participation. 12 instructors and 26 students from 10 universities declared that they would attend, and they attended. They were requested to come with a 3D product model created in CAD software such as Rhinoceros, Solidworks, 3ds Max, Autocad, etc.

The study was carried out with 38 participants in a seminar hall in Istanbul Technical University Faculty of Architecture on 28 November 2017. Two VR stations were established on two opposite sides of the scene platform of the hall and were made ready to use before the study (Figure 5.4). In this study, Autodesk Vred software and HTC Vive headsets were used with room-scale setups.

[9] The preliminary findings of this part of the study were presented with a quick and dirty analysis of raw data in the 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT) and published by IEEE in IEEE Xplore Digital Library as a conference proceeding. doi: 10.1109/ISMSIT.2018.8567058

Figure 5.4 : Locations of VR stations in the hall.

In the first part of the study, Evren Arın who is an expert from Autodesk and Çetin Yıldırım who is an expert from PENTA Technology gave some information about what virtual reality is, what designers can do by this technology, and what the usage areas of VR in design and production processes are, etc. (Figure 5.5).

Figure 5.5 : Presentations of Evren Arın (up) and Çetin Yıldırım (down).

In the second part of the study, how a 3D model could be imported into the software (Autodesk Vred), how it is transformed, how materials are created, how the created materials assign to the 3D model, and, in the end, how it is experienced in the VR environment were demonstrated. And then, participants, one-by-one, tried to perform these steps with the 3D models brought with them (Figure 5.6 and Figure 5.7).

After the trial sessions, participants filled out an online questionnaire prepared in advance (Figure 5.8). The details about this questionnaire are presented below.

In the last part of the study, a discussion session was held with participants. In this session, participants expressed and discussed their positive or negative opinions about the use of VR technology in industrial design education (Figure 5.9). This session was recorded both with a video camera and a sound recorder.

Figure 5.6 : A participant trying Vred software.

Figure 5.7 : A participant experiencing the 3D model in the VR environment.

Figure 5.8 : Participants filling out the online questionnaire.

Figure 5.9 : A frame from the discussion session.

Questionnaire

The questionnaire used in this preliminary study can be handled in three sections: (i) participant profile; (ii) scale items; and (iii) open-ended questions. The entire questionnaire form prepared in Turkish is presented in Appendix B.

Participant profile:

This part of the questionnaire includes five questions regarding *age, sex, educational status, current position in the affiliated university* (student or instructor), and *the familiarity with VR equipment used in the study*.

Scale items:

As mentioned in the previous chapter, there are two main approaches regarding the adoption[10] of technology: *technology acceptance* and *product acceptance*. Product acceptance models (see Chapter 3) are mainly based on the usability / user experience methodology. However, according to Norman (1998), "in the early days of technology, it doesn't matter if it is hard to use" (p. 24) for early adopters, and usability / user experience can only affect the late adopters' acceptance of the technology. The days in which this preliminary study was planned and performed (the second half of 2017) were the early days of VR technology for users in Turkey. Therefore, technology acceptance models and theories were chosen as a primary base for the scale (Likert scale) items of the questionnaire, and usability metrics were considered as secondary or supporting sources.

Among technology acceptance models and theories, as aforementioned, UTAUT is constructed by unifying four former theories and four former models, and UTAUT2 is the extended version of it. Therefore, UTAUT2 can be defined as the most comprehensive model for the analysis of technology acceptance. Also, according to the comparison of technology acceptance models and theories in terms of their power for explanation and prediction delivered in Chapter 3, UTAUT2 is the one that has a better explanation and prediction power for 'intention to use' when compared to the other models and theories. For these reasons, the scale items regarding the insights of using VR technology in industrial design education were prepared based on the items of UTAUT2. However, the items belonging to the constructs which are *Social Influence*, *Facilitating Conditions*, *Price Value* and *Habit* were excluded as these items refer to long-term experience, but this preliminary study is based on participants' first-time experience. Hence, they do not apply to this study.

Last but not least, the items of *Hedonic Motivation* in UTAUT2' questionnaire are as follows:

— HM1. Using mobile Internet is fun.

— HM2. Using mobile Internet is enjoyable.

[10] Adoption, noun, (starting to use): Accepting or starting to use something new (Cambridge Dictionary, 2020a)

— HM3. Using mobile Internet is very entertaining.

However, Mutlu (2016) who conducted a study by using the items of UTAUT2 with Turkish participants reported that "an English speaker could be able to distinguish these three questions, however, in Turkish, 'fun', 'enjoyable', and 'entertaining' mean the same thing and there are not words which correspond to them separately" (p. 130). She also reported that one of these questions was removed from the Turkish version of her survey, which otherwise would be the repetition of the same thing. For this reason, as a precaution against this situation, these items of *Hedonic Motivation* were merged into one item as "Using VR technology is fun/ enjoyable/ entertaining."

The final versions of the scale items adapted from the UTAUT2 questionnaire are presented in Table 5.1. All these items were asked on 7-point Likert scales (1 = "strongly disagree" to 7 = "strongly agree")

On the other hand, ISO 9241-11 (2018) describes usability as the "extent to which a system, product or service can be used by specified users to achieve specified goals with *effectiveness*, *efficiency* and *satisfaction* in a specified context of use" (p. 2), and according to ISO-IEC 25022 (2016), usability metrics for

— *"effectiveness"* measure "the accuracy and completeness with which goals can be achieved" (p. 34),

— *"efficiency"* measure "the level of effectiveness achieved to the expenditure of resources" (p. 34),

— *"satisfaction"* measure "the extent to which users are free from discomfort and their attitudes towards the use of the product" (p. 34).

In other words, usability metrics for *effectiveness* are the metrics regarding "the accuracy and completeness with which users achieve specified goals", usability metrics for *efficiency* are the metrics regarding "the resources expended in relation to the accuracy and completeness with which users achieve goals", and usability metrics for *satisfaction* are the metrics regarding "the comfort and acceptability of use" (Mifsud, 2015).

All in all, this preliminary study focuses on collecting the attitudinal data on the acceptability of a new technology. For this reason, based on the literature review mentioned above, it was decided to be benefitted from usability metrics for *satisfaction*

as well, which are related to the attitudes towards the use of the product and the acceptability of use.

Usability metrics for *satisfaction* are generally categorized into two major groups: *task level satisfaction metrics*, and *test level satisfaction metrics*. Task level satisfaction metrics measure separately the difficulty level of each task or scenario for the use of a product or system, whereas test level satisfaction metrics measure the difficulty level of the overall use, which includes various tasks and scenarios, of the product or the system (Mifsud, 2015). This preliminary study was not conducted with the actual use scenario of a VR technology, and just two tasks defined beforehand were asked participants to be performed that are: (1) to prepare their 3D CAD model to experience it in the VR environment; and (2) to experience it in the VR environment. For this reason, task level satisfaction metrics were considered more appropriate for this preliminary study.

The well-known and widely used task level satisfaction metrics in the literature are:

- After Scenario Questionnaire (ASQ)
- NASA Task Load Index (NASA-TLX)
- Subjective Mental Effort Questionnaire (SMEQ)
- Usability Magnitude Estimation (UME)
- Single Ease Question (SEQ)

Of these metrics, Single Ease Question (SEQ) is recommended by Sauro (2010) because it is short, and easy to respond to, manage, and score (Mifsud, 2015). From this point of view, two items adapted from SEQ were added to scale items of the questionnaire for measuring the difficulty levels of the two tasks that the participants are asked to perform.

The last item added to scale items was adapted from the “Net Promoter Score (NPS)” question. NPS is actually “a metric that quantifies how many more people are likely to strongly recommend your ... product compared to those likely to criticize it” (Fessenden, 2016), and was developed to measure customer loyalty in business field with a single question: How likely is it that you would recommend [this product, service, company, etc.] to a colleague or friend? However, it has a close relationship with the perception of user experience, and scores of satisfaction questions in usability

metrics are well-correlated with NPS. If most of the users are reporting high NPS scores by putting their own reputations on the line to recommend a product, that product has a high chance of being accepted as usable (Fessenden, 2016). As a result, an NPS item was added by adapting not for measuring loyalty level of participants but for interpreting the acceptability of VR technology.

Adapted versions of all scale items of the questionnaire are presented in Table 5.3.

Table 5.3 : Scale items of the questionnaire.

Code	Item
PE1	I think using VR technology in industrial design studio courses will be useful.
PE2	Using VR technology helps me accomplish things more quickly.
PE3	Using VR technology will increase my productivity.
EE1	Learning how to use VR technology will be easy for me.
EE2	My interaction with VR technology is clear and understandable.
EE3	I think VR technology is easy to use.
EE4	It will be easy for me to become skillful at using VR technology.
HM	Using VR technology is fun/ enjoyable/ entertaining.
BI1	I intend to continue using VR technology in the future.
BI2	I will always try to use VR technology in industrial design studio courses.
BI3	I plan to continue to use VR technology frequently.
SEQ1	I think making the 3D model ready to experience (creating and assigning materials, etc.) in the virtual reality (VR) environment was ...
SEQ2	I think experiencing the 3D model that I had transferred to the virtual reality (VR) environment in the VR environment was...
NPS	On a scale of 0 to 10, how likely is it that you would recommend this VR technology to a friend or colleague for using it in industrial design studio courses?

PE: Performance Expectancy, **EE**: Effort Expectancy, **HM**: Hedonic Motivation, **BI**: Behavioral Intention, **SEQ**: Single Ease Question, **NPS**: Net Promoter Score

Open-ended questions:

Two open-ended questions asking participants to write their positive and negative opinions about using this type of VR technology in industrial design education were added to the end of the questionnaire so that they could report their opinions in an unstructured format as well.

Group Discussion

Payne & Payne (2004) describe “group discussion” as “a means of collecting data in one go from several people (who usually share common experiences) and which

concentrates on their shared meanings" (p. 103). It is similar to the method *focus group*, but different from it. Focus group is a special type of group discussion which is conducted with a smaller participant group (Payne & Payne, 2004). A focus group discussion is typically carried out with 6 to 12 participants, whereas a group discussion is conducted with a larger participant group (Van Eeuwijk & Angehrn, 2017). The other differences between them are presented in Table 5.4.

Table 5.4 : Differences between the focus group and group discussion, adapted from (Van Eeuwijk & Angehrn, 2017, p. 1).

	Focus Group	**Group Discussion***
Participants	Multiple participants who share one (some) common characteristic(s) that is (are) meaningful from the research perspective.	Multiple participants who gather at the same place and have certain knowledge of the study subject.
Mode of Conduct	Semi-structured; carefully planned and cautiously executed.	Unstructured, without clear roles assigned to participants; no clear-cut scenario.
Scope of Insights	Often a large spectrum of opinions, notions and/or experiences; added focus on social interaction between participants.	Often a large but scattered spectrum of opinions, notions and/or experiences.
Level of Focus	High level of focus on the given topic(s).	Level of focus largely uncontrollable.
Degree of Participation	When accurately and adequately moderated, all participants contribute equally to the discussion.	Usually, one or a few participants dominate and shape the discussion.

*: conceptualized as a regular meeting in the study of Van Eeuwijk & Angehrn (2017).

According to Payne & Payne (2004), in the early stages of research, group discussion method is a useful tool to explore possible lines of inquiry and to reveal thoughts, ideas, and feelings of the representative group about the research topic.

For these aforementioned reasons, and with the thought that the participants will express their opinions with their explanations more clearly and understandably in front of the community, a group discussion session with participants was conducted as the last part of the preliminary study. In this part of the study, it was aimed to reveal the participants' positive and negative opinions verbally and to capture sentences explaining the reasons behind their opinions. In this session, two moderators were employed. One was responsible for ensuring the session to progress smoothly, whereas the other was responsible for making sure that all participants who want to talk were covered, discussed issues were relevant to the research subject, and the session was not dominated or forced by any participant.

5.1.2.2 Analyses of the collected data

Descriptive statistics of the multiple-choice and Likert-scale questions

The answers given to multiple-choice and Likert-scale questions were analyzed by descriptive statistics. According to the analysis of participant profile questions, 6 out of 12 instructors and 20 out of 26 students are female (Table 5.5). 20 out of 26 students are 4th grade, 3 are 3rd grade and 3 are 2nd grade (Table 5.6). The instructors' ages range from 26-56 years old, and the students are aged between 19 and 26 years old.

Table 5.5 : Gender distribution of participants.

Gender	Student	Instructor	Total	Percent
Female	20	6	26	68.4
Male	6	6	12	31.6

Table 5.6 : Grade distribution of students.

Grade	Number	Percent
2nd Grade	3	11.5
3rd Grade	3	11.5
4th Grade	20	76.9

Participants' familiarity status with the examined VR technology is presented in Figure 5.10. According to this, 17 out of 38 participants were not familiar with VR technology, 18 had low familiarity, and only 3 had high familiarity. However, 'familiarity' here refers to the familiarity with the VR equipment used, not to the familiarity with using it in industrial design practices. As understood from the transcription of the discussion session's record, none of the participants have used this type of VR equipment in any of their works related to industrial design before this study. The low or high familiarity of participants comes from their game and/or entertainment experiences.

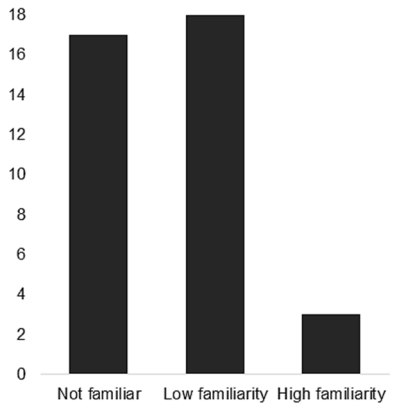


Figure 5.10 : Ratings of participants' familiarity with the VR headsets.

Table 5.7 : Means and standard deviations of scale items (N=38).

Code	Item	Mean	Std. Deviation
PE1	I think using VR technology in industrial design studio courses will be useful.	6.05	0.957
PE2	Using VR technology helps me accomplish things more quickly.	5.42	1.056
PE3	Using VR technology will increase my productivity.	5.84	0.916
EE1	Learning how to use VR technology will be easy for me.	5.87	0.935
EE2	My interaction with VR technology is clear and understandable.	6.08	0.941
EE3	I think VR technology is easy to use.	5.55	0.950
EE4	It will be easy for me to become skillful at using VR technology.	5.66	0.938
HM	Using VR technology is fun/ enjoyable/ entertaining.	6.39	0.718
BI1	I intend to continue using VR technology in the future.	5.50	0.923
BI2	I will always try to use VR technology in industrial design studio courses.	4.92	1.421
BI3	I plan to continue to use VR technology frequently.	4.97	1.241
SEQ1	I think importing the 3d model into the software and making some arrangements (creating and assigning a material, etc.) to experience it in the virtual reality (VR) environment was ...	5.63	1.282
SEQ2	I think experiencing the 3D model that I had transferred to the virtual reality (VR) environment in the VR environment was...	5.55	1.389
NPS	On a scale of 0 to 10, how likely is it that you would recommend this VR technology to a friend or colleague for using it in industrial design studio courses?	8.89	1.521

Cronbach's Alpha Score: 0.866

On the other hand, all scale items except the NPS item, which was asked on 10-point scale (0= "Not at all likely" to 10= "Extremely likely"), were asked on 7-point Likert scales (for the items adapted from UTAUT2, 1 = "strongly disagree" to 7 = "strongly agree"; for the items adapted from SEQ, 1 = "very difficult" to 7 = "very easy"). As a result of the reliability analysis with SPSS software, Cronbach's Alpha score of scale items was calculated as 0.866. This means that the answers given to these items have high internal consistency. Means and standard deviations of the answers are presented in Table 5.7.

According to the categorized radar graph representations of the results presented in Figure 5.11, in terms of *Performance Expectancy (PE)*, it can be said that participants tend to;

— strongly agree that VR technology will be useful for industrial design education *(PE1)*,

— agree that VR technology will help them accomplish things more quickly to some degree *(PE2)*,

— agree that VR technology will increase their productivity *(PE3)*.

In terms of *Effort Expectancy (EE)*, they tend to;

— agree that learning how to use it will be easy for them *(EE1)*,

— agree that their interaction with the technology is clear and understandable *(EE2)*,

— think that VR technology is not so easy to use *(EE3)*,

— agree that becoming skillful at using it will be easy for them *(EE4)*.

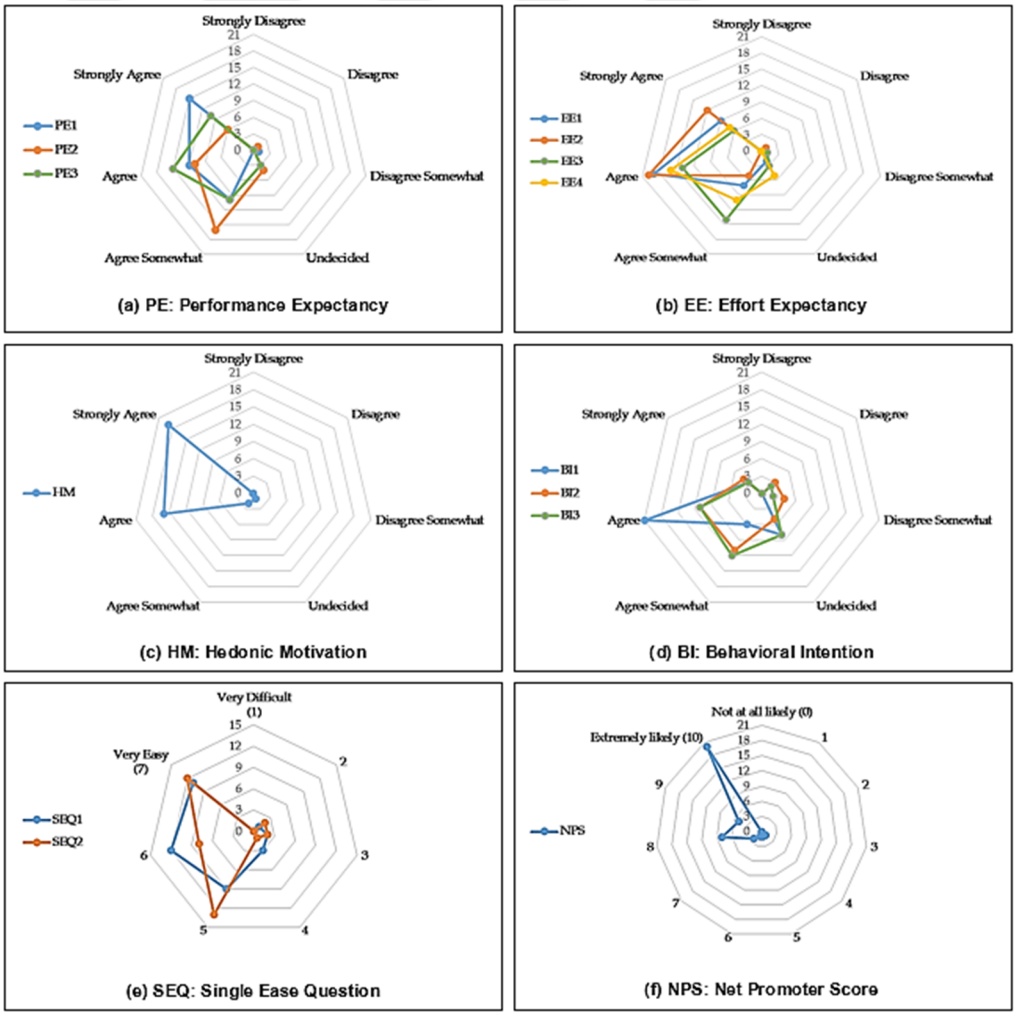


Figure 5.11 : Categorized radar graphs of the items' results.

In terms of *Hedonic Motivation (HM)*, they tend to strongly agree that using VR is fun/enjoyable/entertaining.

In terms of *Behavioral Intention (BI)*, although they tend to agree that they have the intention to continue using VR in the future, it is seen that they are not so sure for continuous use of it individually or in industrial design studio courses.

In terms of *Single Ease Questions (SEQs)*, they tend to think that importing the 3D model into the software and making some arrangements to experience it in the VR environment is easy *(SEQ1)* and experiencing it in the VR environment is not so easy *(SEQ2)*.

Finally, in terms of *Net Promoter Score (NPS)*, they tend to strongly recommend this type of VR technology to their friends or colleagues for using it in industrial design studio courses.

Content analysis of the written and the verbal data

Content analysis is an analysis method described by Kripendorff (2004) as "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use" (p. 18). It can be quantitative or qualitative. Quantitative content analysis concentrates on counting and measuring, whereas qualitative content analysis concentrates on interpreting and understanding (Luo, 2019). In other words, in quantitative content analysis, main aim is to cultivate numerical data that can be processed statistically, while in qualitative content analysis, main aim is to understand and interpret the contextual meaning of the content (Hall, 2018). So, with quantitative content analysis *how frequently what they say* can be depicted, whereas with qualitative content analysis *why they say so* can be understood and interpreted. In this preliminary study, it was aimed to figure out both what participants think and why they think so. Therefore, written and verbal data were analyzed together both quantitatively and qualitatively by the content analysis method. Erlingsson & Brysiewicz (2017) published a hands-on guide for doing content analysis, which was prepared based on 15 studies from literature that also include the well-known and most cited works such as Mayring (2014) and Krippendorff (2004). In this guide, the process for analyzing the data from verbatim to overarching themes was depicted as in Figure 5.12. Descriptions of the terms used in this guide were presented as in Table 5.8. The analysis of data was conducted by following the steps of this hands-on guide, and the table of the content analysis of instructors' written and

verbal data in this preliminary study is presented in Table A.4 of Appendix A as an example.

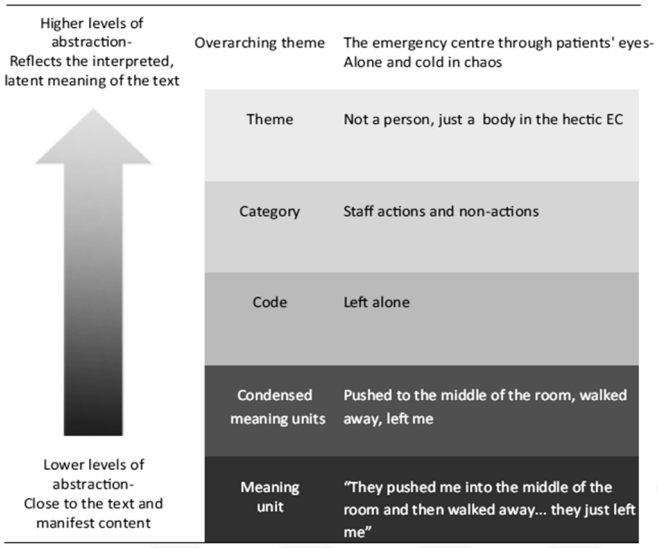


Figure 5.12 : Example of content analysis leading to higher levels of abstraction from manifest to latent content, taken from (Erlingsson & Brysiewicz, 2017, p. 94).

Table 5.8 : Glossary of terms used in the hands-on guide of content analysis, taken from (Erlingsson & Brysiewicz, 2017, p. 94).

Term	Explanation
Condensation	Condensation is a process of shortening the text while still preserving the core meaning
Code	A code can be thought of as a label; a name that most exactly describes what this particular condensed meaning unit is about. Usually one or two words long.
Category	A category is formed by grouping together those codes that are related to each other through their content or context. In other words, codes are organized into a category when they are describing different aspects, similarities or differences, of the text's content that belong together. When analysis has led to a plethora of codes, it can be helpful to first assimilate smaller groups of closely related codes in sub-categories. Sub-categories related to each other through their content can then be grouped into categories. A category answers questions about who, what, when, or where? In other words, categories are an expression of manifest content, i.e., what is visible and obvious in the data. Category names are factual and short.
Theme	A theme can be seen as expressing an underlying meaning, i.e., latent content, found in two or more categories. Themes are expressing data on an interpretative (latent) level. A theme answers questions such as why, how, in what way, or by what means? A theme is intended to communicate with the reader on both an intellectual and emotional level. Therefore poetic and metaphoric language is well suited in theme names to express underlying meaning. Theme names are very descriptive and include verbs, adverbs and adjectives.

The quantitative content analysis of written and verbal data was done in a general categorization as negative opinions and positive opinions based on the condensed meanings of the verbatim data. By this analysis, it was aimed at revealing the general

attitudes of industrial design students and instructors towards the use of VR technology in industrial design education. Whereas Figure 5.13 shows the overall attitudes of all participants, in Figure 5.14 and Figure 5.15, instructors' and students' attitudes are depicted separately. In Figure 5.13, it can be seen that 37 different sentences containing positive opinions were expressed by participants 101 times in total, whereas 43 sentences containing negative opinions were expressed by them 70 times[11]. On the other hand, 26 out of these 37 sentences containing positive opinions were expressed by instructors 38 times, and 23 out of them were expressed by students 63 times. Additionally, 36 out of these 43 sentences containing negative opinions were expressed by instructors 43 times, and 17 out of them were expressed by students 27 times. According to these results of the quantitative content analysis of written and verbal data, it can be said that before the actual use of VR technology in the in-studio study, instructors had a slightly negative attitude towards the use of it in industrial design education whereas students had a positive attitude.

The qualitative content analysis of written and verbal data was done separately based on the categories generated from data. The understandings and the interpretations of what participants think and why they think so are presented below separately according to these categories.

Regarding *Design Representation*, participants think that VR makes a full-scale real-like 3D experience of the design possible without a physical model by enabling individuals to experience the design in a very realistic way on a 1:1 scale and in 3D without prototyping or model making. Therefore, it can be used instead of physical model or mock-up. Hence, it both decreases the need for model making or prototyping, and enables individuals to experience the designs that are so big where making their prototypes and models is too hard or impossible (Figure 5.16).

Regarding *Design Evaluation*, on one hand, participants think that VR: enables individuals to get an insight about the dimensions of the design and the user-product relationship without prototyping or model making; enables a better and accurate perception of the design; facilitates the evaluation of design details by offering a full-scale real-like 3D experience of the design without a physical model and by enabling

[11] If a participant expressed a sentence more than once, that sentence was accepted as if it was stated once by that participant.

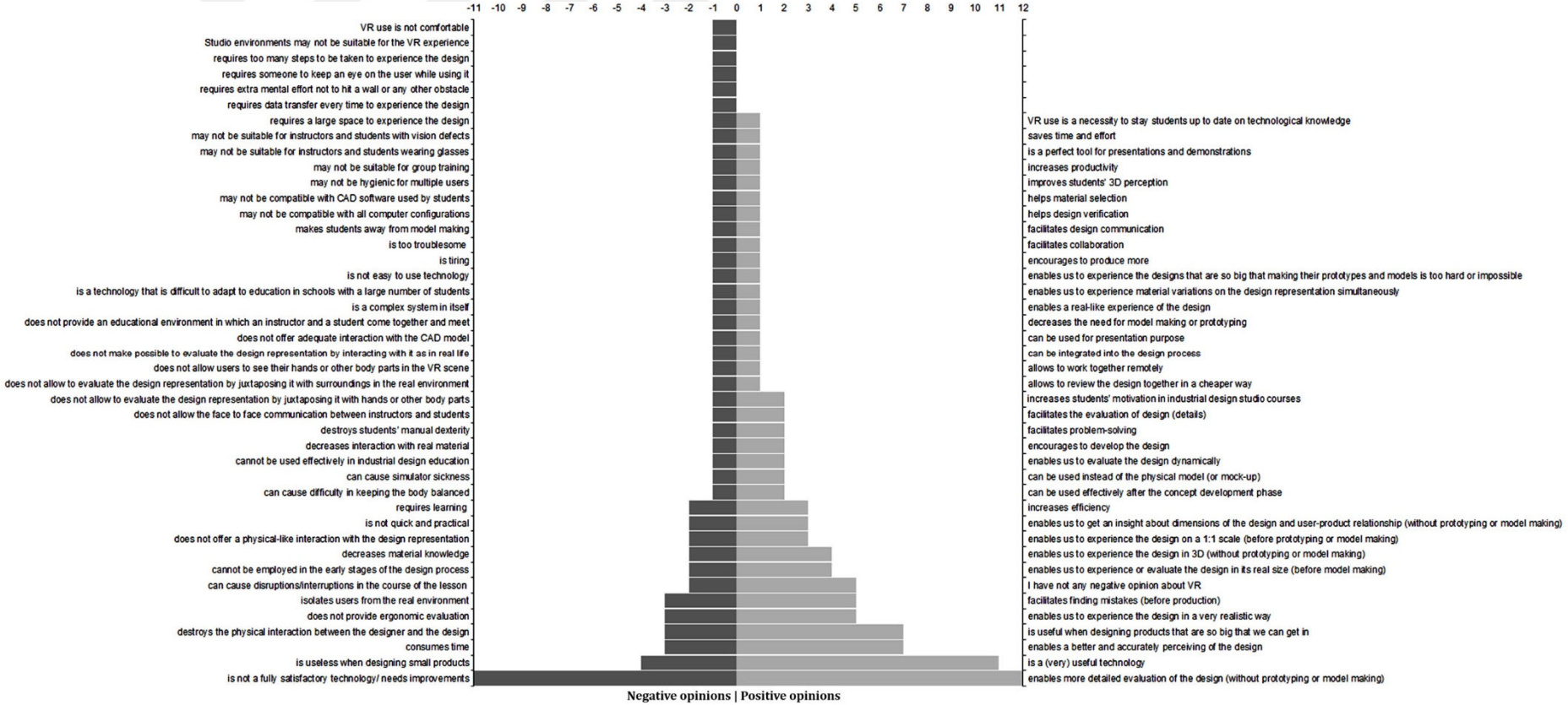


Figure 5.13 : Results of the quantitative content analysis of all participants' written and verbal data.

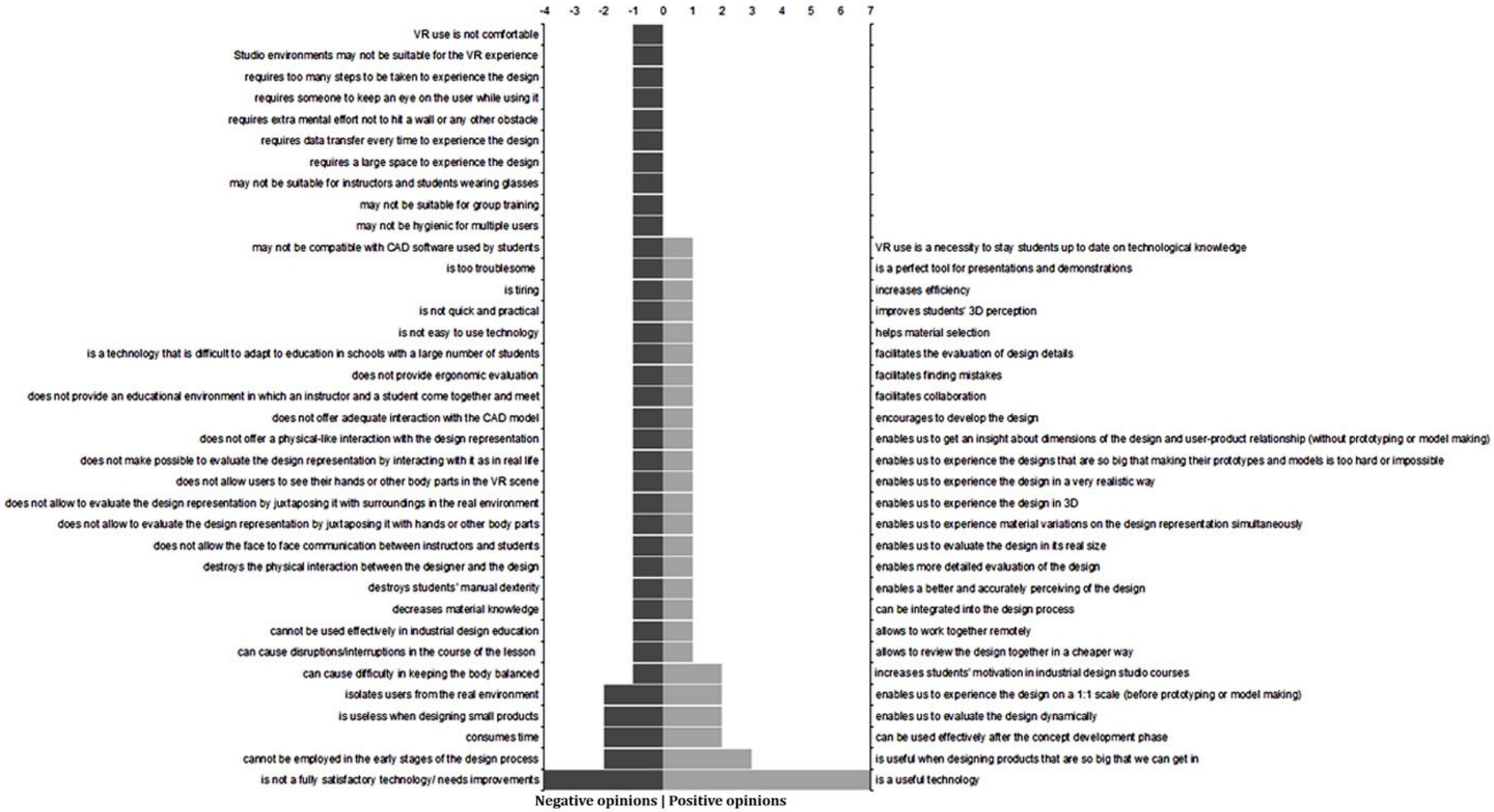


Figure 5.14 : Results of the quantitative content analysis of the instructors' verbal and written data.

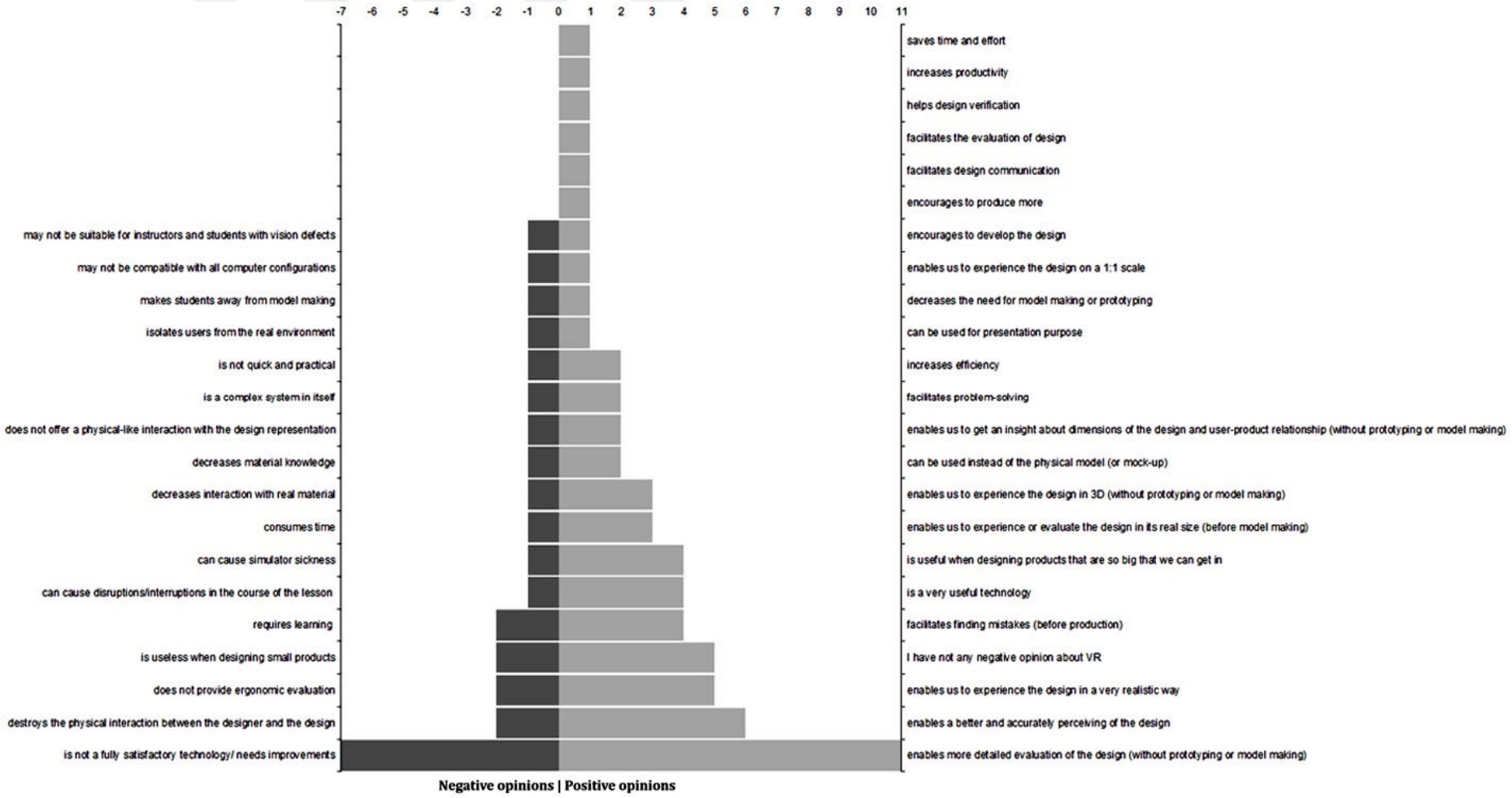


Figure 5.15 : Results of the quantitative content analysis of the students' verbal and written data.

individuals to evaluate the design in its real size dynamically. Therefore, it enables a more detailed evaluation of the design without prototyping or model making. Hence, it facilitates finding mistakes and helps design verification. On the other hand, they think that due to user isolation from the real environment, not offering a physical-like interaction with the design representation, and not allowing users to see their hands or other body parts in the VR scene, VR does not make the evaluation of the design representation possible by interacting with it as in real life and it does not allow individuals to evaluate the design representation by juxtaposing it with hands or by other body parts, or with the surroundings in the real environment. Therefore, according to the participants, VR does not provide an ergonomic evaluation. Hence, it is useless when designing small products although it is found useful when designing products that are so big that individuals can get in it (Figure 5.17).

Regarding *Design Development*, potential users think that VR helps material selection by enabling individuals to experience material variations on the design representation simultaneously, whereas it facilitates problem-solving by finding mistakes. Therefore, potential users think that it encourages to produce more and to develop the design (Figure 5.18).

Regarding *Design Presentation*, participants think that as VR technology enables a better and accurate perception of the design by offering a full-scale real-like 3D experience of the design without a physical model, it not only facilitates design communication but also it can be used for presentation purposes. Besides, it is a perfect tool for presentations and demonstrations (Figure 5.19).

Regarding *Design Process*, although instructors think that VR can be integrated into the design process, they state that it is a CAD-based technology, and it can be used after the design reaches a certain maturity level. Accordingly, they think that VR cannot be employed in the early stages of the design process. However, instructors believe that it can be used effectively after the concept development phase (Figure 5.20).

Regarding *Collaboration*, instructors think that VR facilitates collaboration by allowing individuals both to work together remotely and to review the design together in a cheaper way (Figure 5.21).

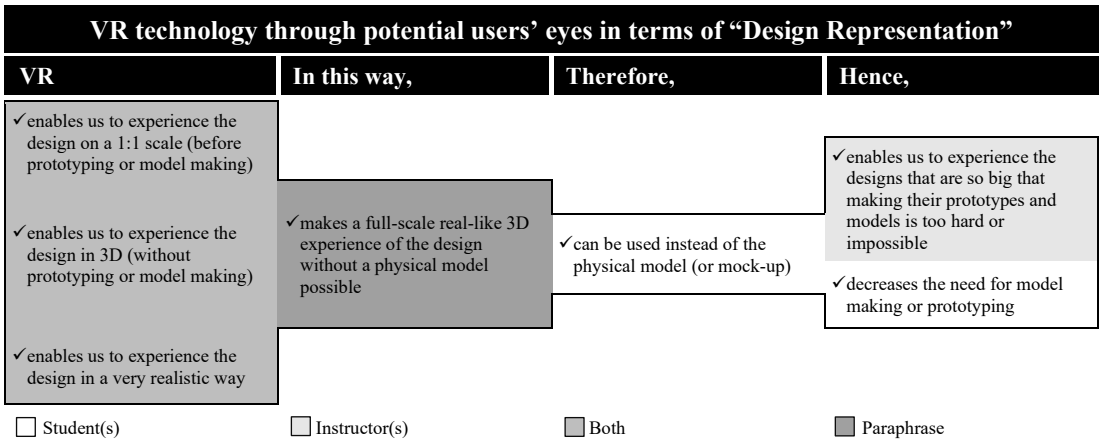


Figure 5.16 : VR technology through potential users' eyes in terms of "Design Representation".

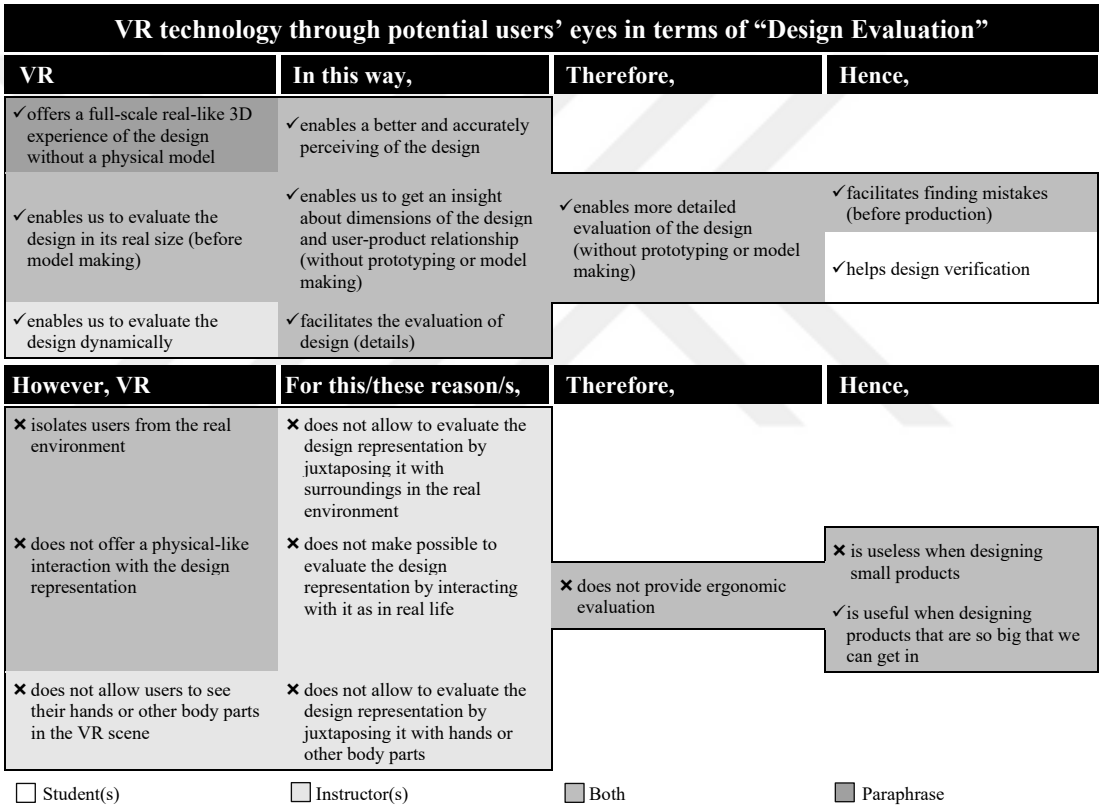


Figure 5.17 : VR technology through potential users' eyes in terms of "Design Evaluation".

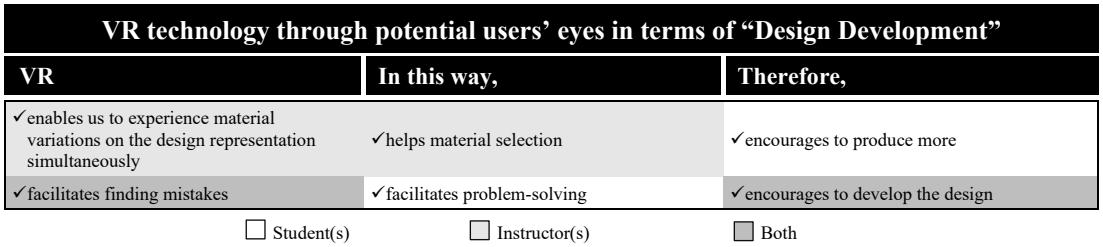


Figure 5.18 : VR technology through potential users' eyes in terms of "Design Development".

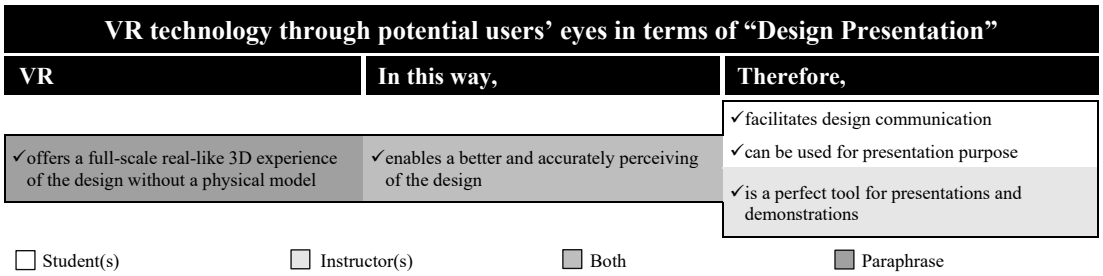


Figure 5.19 : VR technology through potential users' eyes in terms of "Design Presentation".

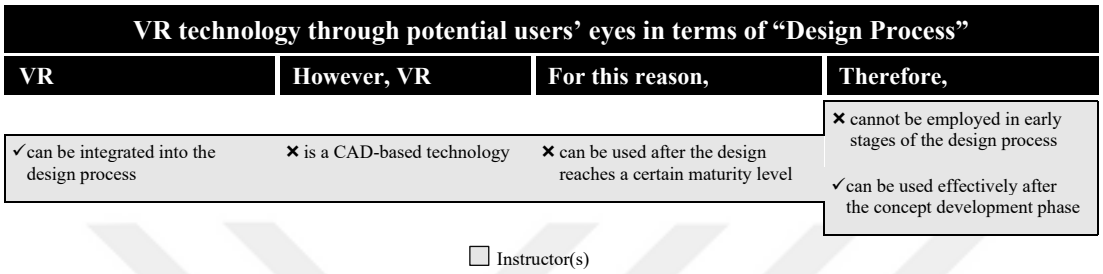


Figure 5.20 : VR technology through potential users' eyes in terms of "Design Process".

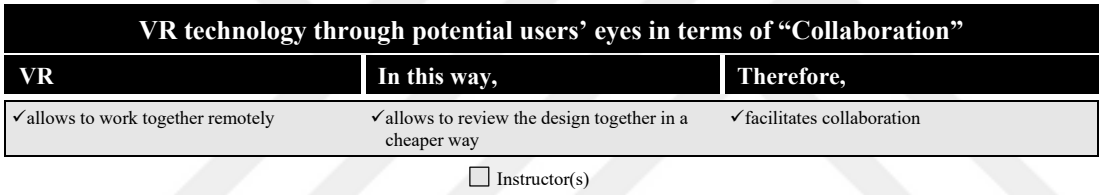


Figure 5.21 : VR technology through potential users' eyes in terms of "Collaboration".

Regarding *Competency Development of Students*, participants, on one hand, think that VR improves students' 3D perception by enabling a better and accurate perception of the design. On the other hand, they think that it makes students away from model making by decreasing the need for model making or prototyping. Not only this but also, they think that it destroys the physical interaction between the designer and the design due to not offering a physical-like interaction with the design representation. Accordingly, they state that, by decreasing interaction with real material, VR will decrease students' not only manual dexterity but also material knowledge (Figure 5.22).

Regarding *Performance of Students*, participants think that VR will increase students' motivation, efficiency, and productivity because it encourages them to develop the design and produce more as it saves time and effort by decreasing the need for model making or prototyping (Figure 5.23).

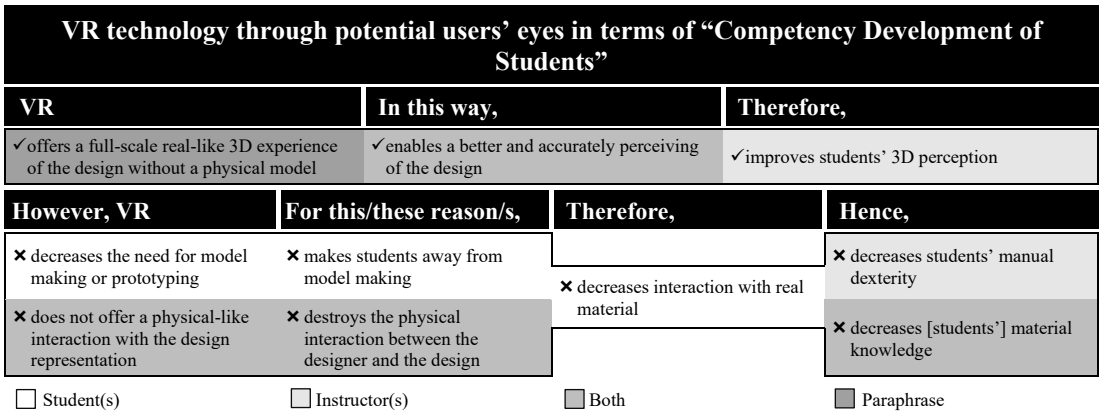


Figure 5.22 : VR technology through potential users' eyes in terms of "Competency Development of Students".

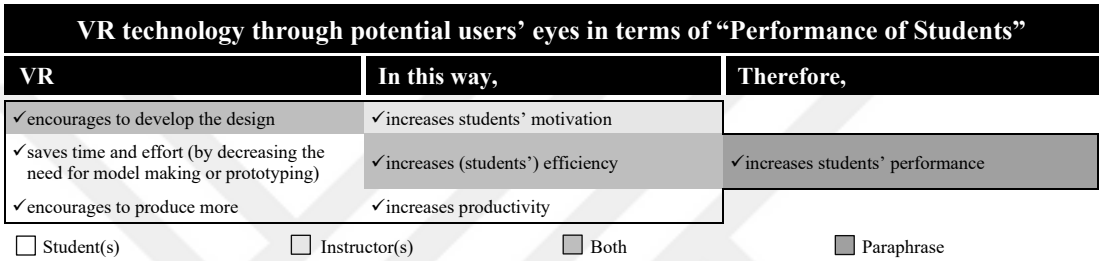


Figure 5.23 : VR technology through potential users' eyes in terms of "Performance of Students".

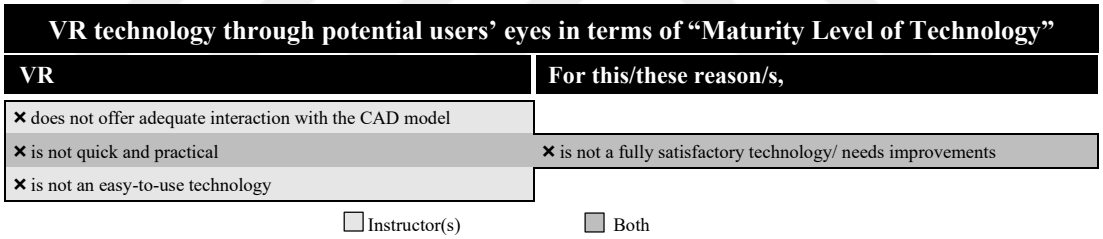


Figure 5.24 : VR technology through potential users' eyes in terms of "Maturity Level of Technology".

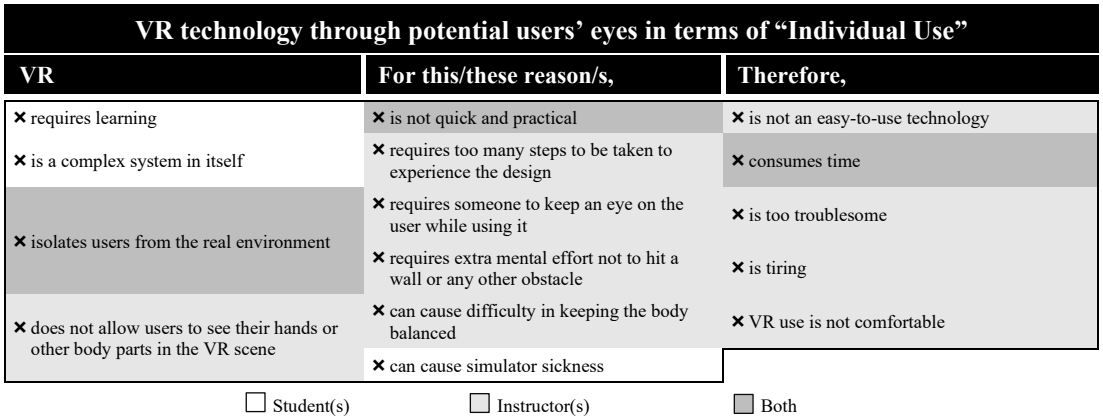


Figure 5.25 : VR technology through potential users' eyes in terms of "Individual Use".

Regarding *Maturity Level of the Technology*, participants think that VR is not a fully satisfactory technology and needs improvements as it does not offer adequate interaction with the CAD model, being quick and practical, and being an easy-to-use technology (Figure 5.24).

Regarding *Individual Use of VR*, according to participants, VR is a complex system, and it requires learning, isolates users from the real environment, and does not allow users to see their hands or other body parts in the VR scene. For these reasons, it: is not quick and practical; requires too many steps to be taken to experience the design; requires someone to keep an eye on the user while using it; requires extra mental effort not to hit a wall or any other obstacle; can cause difficulty in keeping the body balanced; and, can cause simulator sickness. Therefore, it is not an easy-to-use technology; consumes time; is too troublesome and tiring; and, VR use is not comfortable (Figure 5.25).

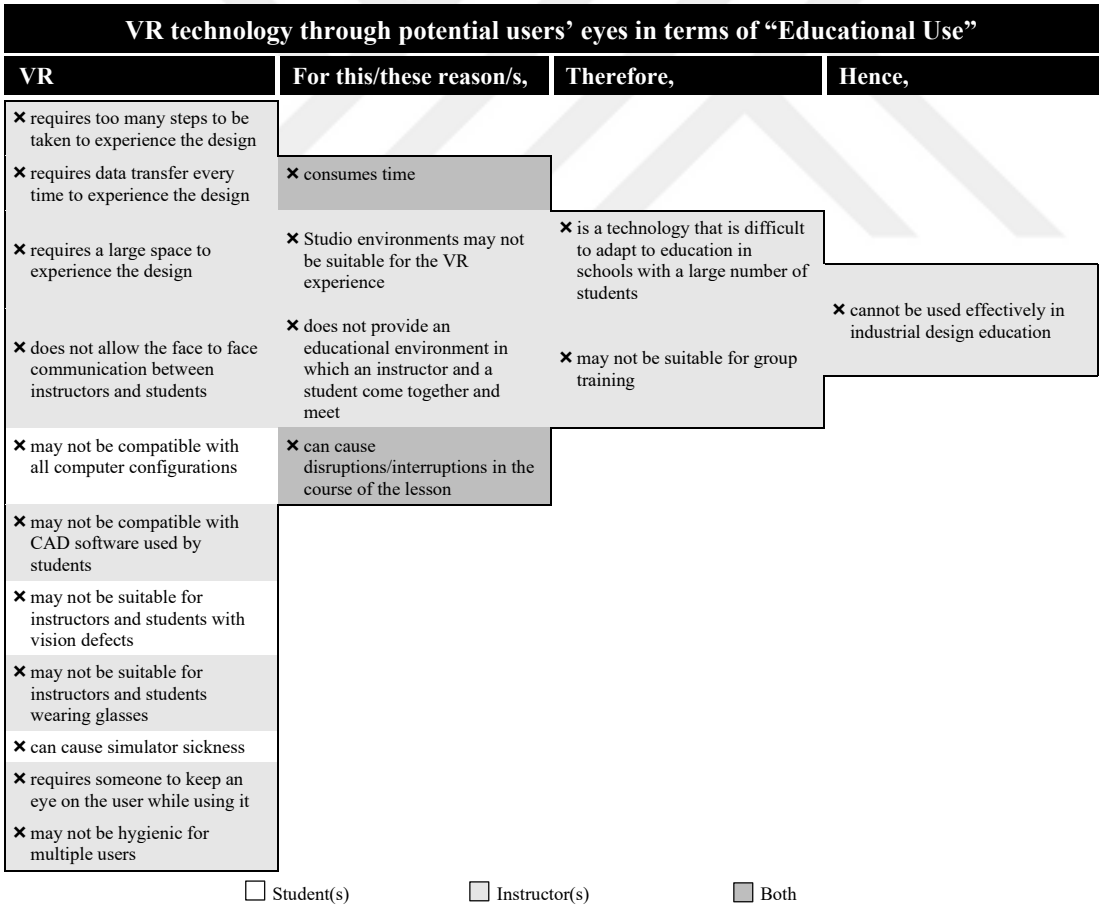


Figure 5.26 : VR technology through potential users' eyes in terms of "Educational Use".

Regarding *Educational Use of VR*, participants think that VR consumes time and can cause disruptions/interruptions in the course of the lesson as it requires: too many steps to be taken to experience the design; data transfer every time to experience the design; and, someone to keep an eye on the user while using it. Besides, it does not provide an educational environment in which an instructor and a student come together and meet as it does not allow face-to-face communication between the instructors and the students. Additionally, they think that it may not be suitable for in-studio use as it requires a large space to experience the design. Last but least, they think that it may not be compatible with all computer configurations and CAD software used by students, may not be suitable for instructors and students with vision defects and wearing glasses, may not be hygienic for multiple users, and it can cause simulator sickness. Therefore, they state that VR may not be suitable for group training, and it is a technology that is difficult to adapt to education in schools with a large number of students. Accordingly, they think that VR cannot be used effectively in industrial design education (Figure 5.26).

5.1.3 Critical outcomes of initial investigations

With these initial investigations, not only the insights of industrial design students and instructors regarding the use of VR technology in industrial design studio courses and the details of former attempts to use it in both professional and educational practices of industrial design were revealed, but also some questions that needed to be answered when planning the in-studio study arose. These questions and their bases from the outcomes of initial investigations are presented in Table 5.9.

Table 5.9 : Some questions that needed to be answered when planning the in-studio study and their bases from some critical outcomes.

Some critical outcomes of the initial investigations	Some questions that are derived from the initial investigations
Scale Items of the Questionnaire (Fig. 5.11) ▪ **PE2:** Participants tend to agree to some degree that VR technology will help them accomplish things more quickly. ▪ **EE3:** Participants tend to agree to some degree that VR technology is easy to use. ▪ **SEQ2:** Participants think that experiencing a 3D model in the VR environment is not so easy.	▪ How can VR be employed in an easy-to-use way?

Table 5.9 (continued) : Some questions that needed to be answered when planning the in-studio study and their bases from some critical outcomes.

Some critical outcomes of the initial investigations	Some questions that are derived from the initial investigations
Content Analysis (Fig. 5.13) Participants think that VR	
• … is time-consuming.	• How can time consumed to use VR be reduced?
• … requires learning.	• How can learning needs for VR use be met?
• … is a complex system in itself.	• How can the complexity level of VR use be reduced?
• … may not be compatible with all computers and CAD software used by students. So, it may not be suitable for classes with lots of students.	• How can VR be made available for lots of students who use different CAD software with different computer configurations?
• … requires a large space.	• How can the space requirement of VR be met within the studio?
• … is useless in designing small products.	• For what kind of product, should VR be employed in the design process?
• …cannot be employed in early stages of the design process.	• At which stage of the design process should VR be involved?
• … may not be hygienic for multiple users.	• How can more than one person use VR hygienically?
Systematic Literature Review VR can be used; ✓ as an inspirational material before the creation of design representations. ✓ as a sketching, modelling, prototyping and visualization tool in creating design representations. ✓ as a presentation, demonstration, experiencing, usability evaluation and ergonomic evaluation tool after the creation of design representations. ✓ as a collaboration tool in and after the creation of design representations.	✓ How will different uses of VR be evaluated within the in-studio study?

5.2 Second Stage: Integration of Virtual Reality

In the second stage of the research, VR technology was tried to be integrated into the educational setting of an industrial design studio course. This section presents the procedures followed, methods used, and results achieved in this stage.

5.2.1 Planning the general framework of the in-studio study

The preliminary study showed that industrial design students and instructors have some reservations about the use of VR technology in industrial design studio courses.

These reservations were accepted as the reservations to be, first of all, eliminated for integrating VR into industrial design education. Therefore, the in-studio study was planned with a focus on getting started by eliminating or minimizing these reservations as much as possible. However, above all, VR is a computer-based technology, and in the educational planning of ITU Department of Industrial Design, students are asked not to use computer technology in the project processes of the 1st and 2nd-grade industrial design studio courses. Also, VR is a CAD-based technology, and in ITU Department of Industrial Design, the compulsory courses in which students are taught CAD software are included in the 2nd-grade curriculum. So, students can only be expected to use computer technology during the project process in 3rd or 4th-grade industrial design studio courses. Moreover, the 4th-grade spring-semester industrial design studio course is the Graduation Project course, and throughout this course, instructors and students come together four times, in total, just for preliminary and final juries after announcing the project brief. In other words, this course just consists of jury sessions and does not involve other studio-based practices of industrial design education such as desk critiques and wall critiques. In addition to these, the results of the preliminary study show that students and instructors may think that VR is useless when designing small products. For these reasons, the 3rd year industrial design studio course "EUT 320E Industrial Product Design III" which was carried out in the 2017-2018 spring semester with the project issue "Smart Electric Minibus Design for Anadolu Isuzu" was selected to conduct the in-studio study. Other decisions taken for planning the in-studio study are presented below with their reasons behind.

— The study of Coburn (2017) and the systematic literature review on related works show that VR can be employed in the design process in industrial design education as a(n) empathy development tool, inspiration tool, design visualization tool, presentation tool, and design evaluation tool. However, the results of the preliminary study revealed that students and instructors think that VR is a good tool for presentations and will be the most useful for design evaluation. Accordingly, jury sessions, which include the participation of all stakeholders of the course and where students present their design ideas with their representations and instructors evaluate them, were considered as the key practices to research how VR technology can be integrated into industrial design education. For this reason, it was decided to make using VR mandatory for design presentation

purposes by students in the jury sessions. However, potential users think that VR cannot be employed in the early stages of the design process because it is a CAD-based technology. Besides, some studies supporting this thought exist in the literature as well. Based on these studies, Ranscombe & Bissett-Johnson (2017) states that in a generic design process CAD and CAD-based tools are mainly used after the concept selection phase (Figure 5.27). Therefore, it was decided to make using VR mandatory for the design presentation purposes by students in the jury sessions after the concept selection phase in the project process. Also, it was decided to support the research by observing and questioning the voluntary use of VR by making it available for use during the studio hours of the course.

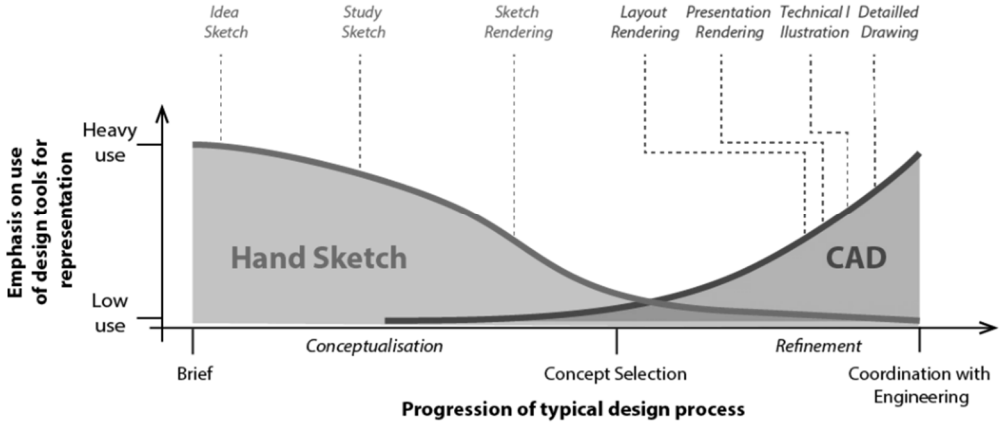


Figure 5.27 : The illustration of the transition between the use of hand sketching and CAD to represent design ideas during the progression of the design process, taken from (Ranscombe & Bissett-Johnson, 2017, p. 3).

— Regarding VR equipment selection to be employed in the in-studio study, VR headsets were reviewed, and the HTC Vive was selected due to its running with PCs, allowing to experience the design at room-scale (Figure 5.28), and having the best tracking performance in mobility (Figure 5.29).

— For this research, additional software was needed to experience the design representations created in CAD software because, in the existing situation, none of the CAD software commonly used by industrial design students could work directly in conjunction with VR headsets. Autodesk Vred software, which is 3D visualization and virtual prototyping software for automotive designers, was employed in the preliminary study as the intermediary software enabling to experience CAD models in VR scenes. However, it was observed that participants had difficulty in using it for experiencing the VR scene, especially in scaling the

3D model according to the user's size and setting the starting position of the camera at the average eye-level height of a person. Besides, Autodesk does not offer free licensing to students and instructors for the educational use of Vred.

Model	Physical connectivity	Tracking system			User behaviour	Recommended working area
		Head tracking	Position tracking	Position tracking methods		
HTC VIVE & VIVE Pro	PC-tethered	O	O	Outside-in	Room scale	Up to 5 m from the base station
Oculus Rift	PC-tethered	O	O	Outside-in	Desktop scale	Up to 2 m from the IR camera
Microsoft MR	PC-tethered	O	O	Inside-out	Desktop scale	Up to 4 m radius from the centre
SONY PSVR	Console-tethered	O	O	Outside-in	Desktop scale	Up to 2 m from the camera
Google daydream	Smartphone	O	X	–	Stationary	Stationary
Samsung Gear VR	Smartphone	O	X	–	Stationary	Stationary

Figure 5.28 : A comparison of the VR devices reviewed for this study, adapted from (Jung & Jeong, 2020, p. 326).

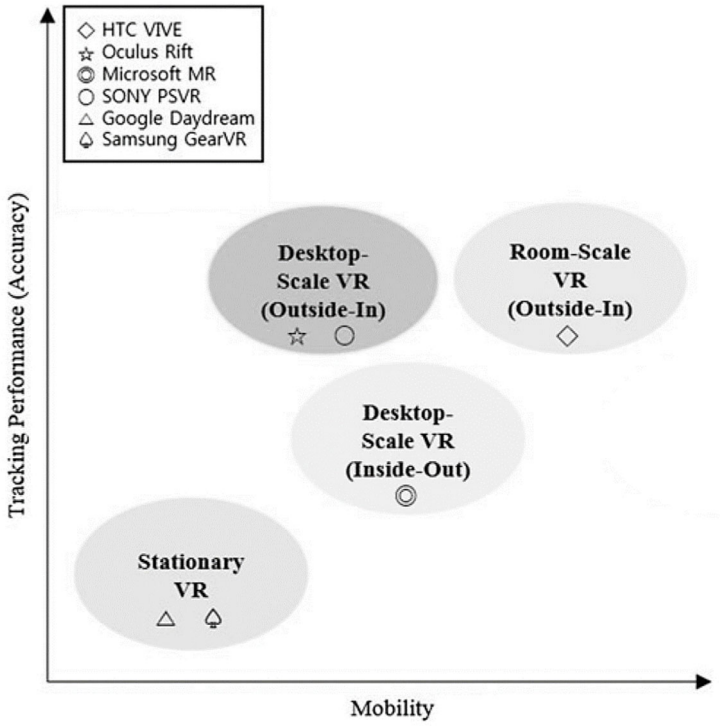


Figure 5.29 : A figure showing the tracking and mobility performances of the VR devices reviewed for this study, adapted from (Jung & Jeong, 2020, p. 327).

For these reasons, other software that can be employed in the in-studio study as intermediary software that will provide communication between the design representations created with CAD software and VR headsets were reviewed. Unity and Unreal Engine, which are game engines, and SimLab Composer 8.0, which is the simulation software, were detected as possible software that can be used. Among these software, SimLab Composer 8.0 was chosen for the 4 main differences.

Firstly, the 2 years free license with full features of SimLab Composer 8.0 for one PC was available for all university students and instructors. Second, SimLab Composer 8.0 was compatible with almost all CAD software commonly used by industrial design students (Figure 5.30) and could be run as integrated with CAD software and embedded in its interface (Figure 5.31). In this way, students would not have to learn all features and/or interface of another software for just experiencing their CAD models in a VR scene.

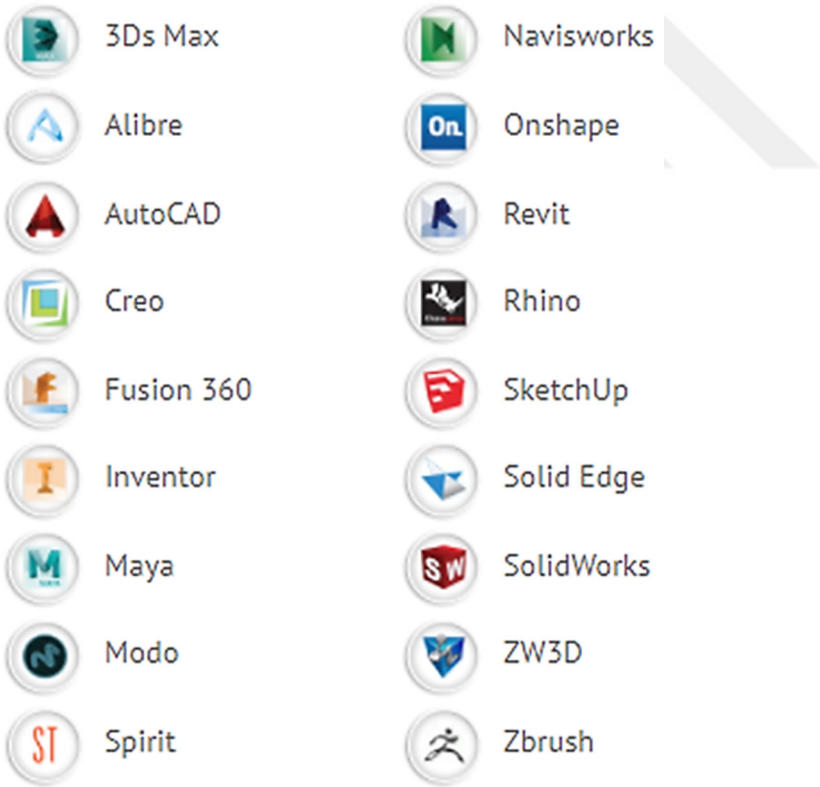


Figure 5.30 : CAD software which SimLab Composer 8.0 is compatible with.

Third, to set the starting position of the camera in the VR scene and the proportion between the viewer and the CAD model, a human figure is employed in SimLab Composer 8.0 (Figure 5.32). The eye position of this human figure refers to the

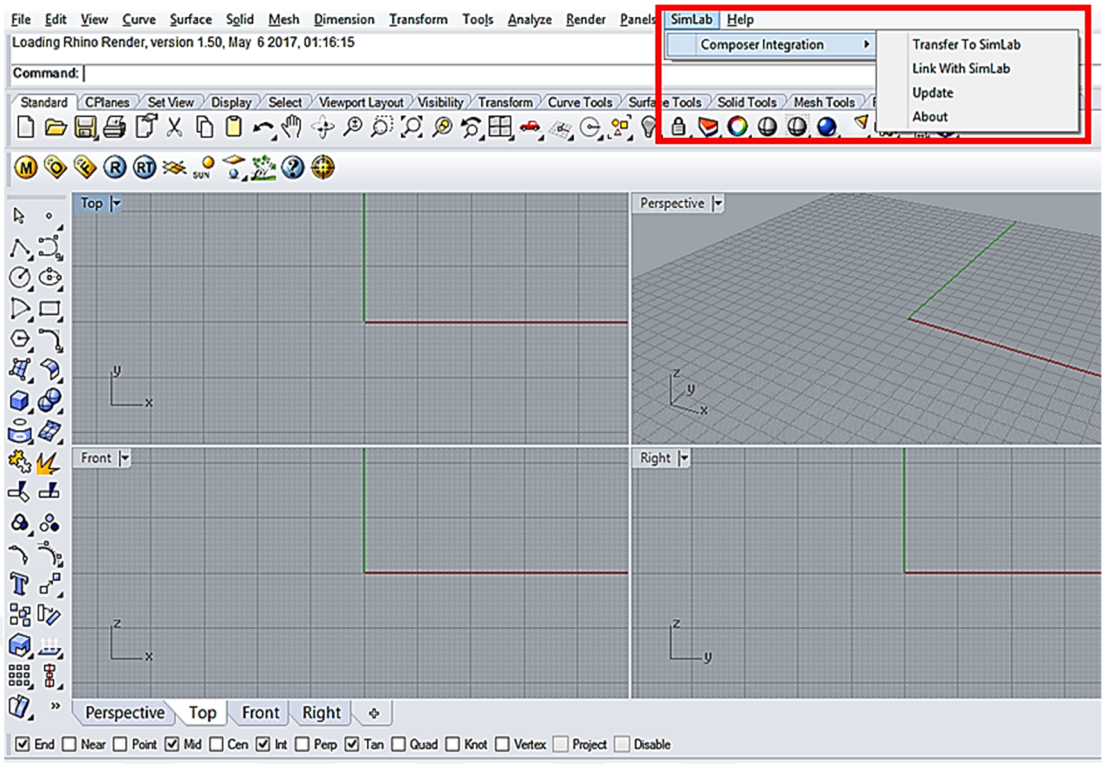


Figure 5.31 : An example of a CAD software interface into which SimLab Composer 8.0 was embedded (Rhinoceros interface).

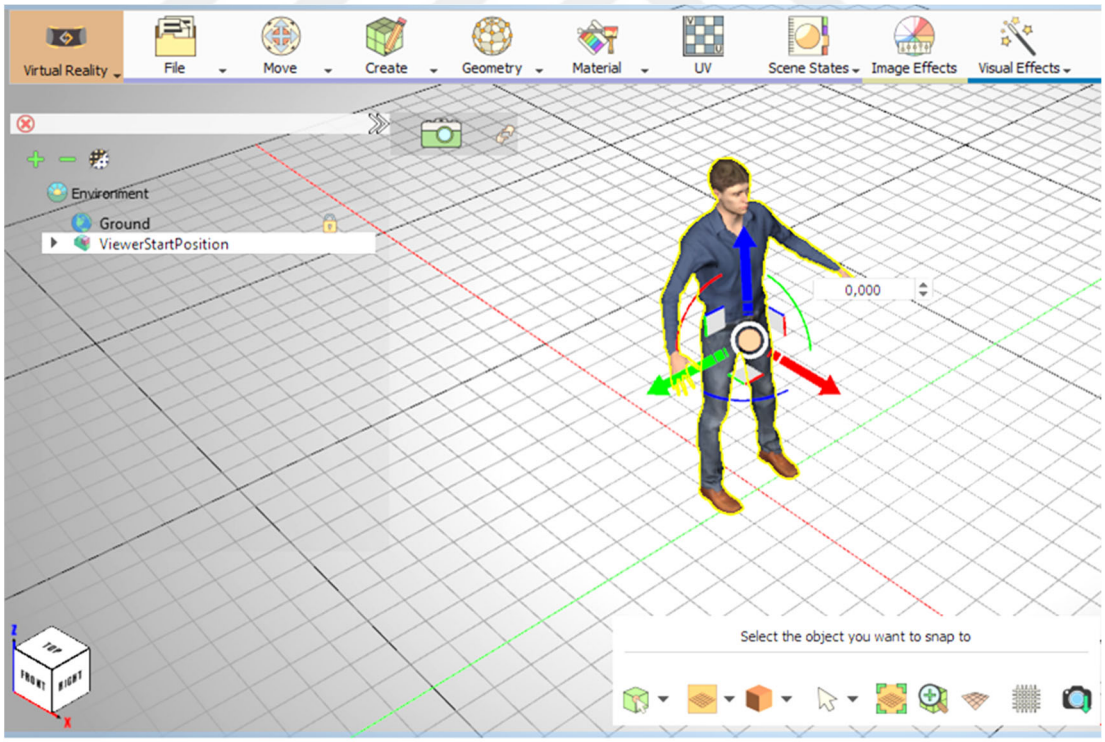


Figure 5.32 : The human figure using to set the starting position of the camera in the VR scene in SimLab Composer 8.0.

starting position of the camera in the VR scene whereas the dimensions of the human figure refer to the dimensions of the viewer. Thus, adjusting the proportion between the viewer and the VR scene elements with the camera positioning in the VR scene, especially positioning the camera at the average eye-level height of a person standing or sitting down, can be done in a more naturalistic way.

Finally, SimLab Composer 8.0 has a desktop VR mode which enables to test the prepared VR scene by viewing it on the computer screen without the need for connection with a VR headset (Figure 5.33). In this way, students can check whether their VR scenes will work properly or not, even without a VR headset.

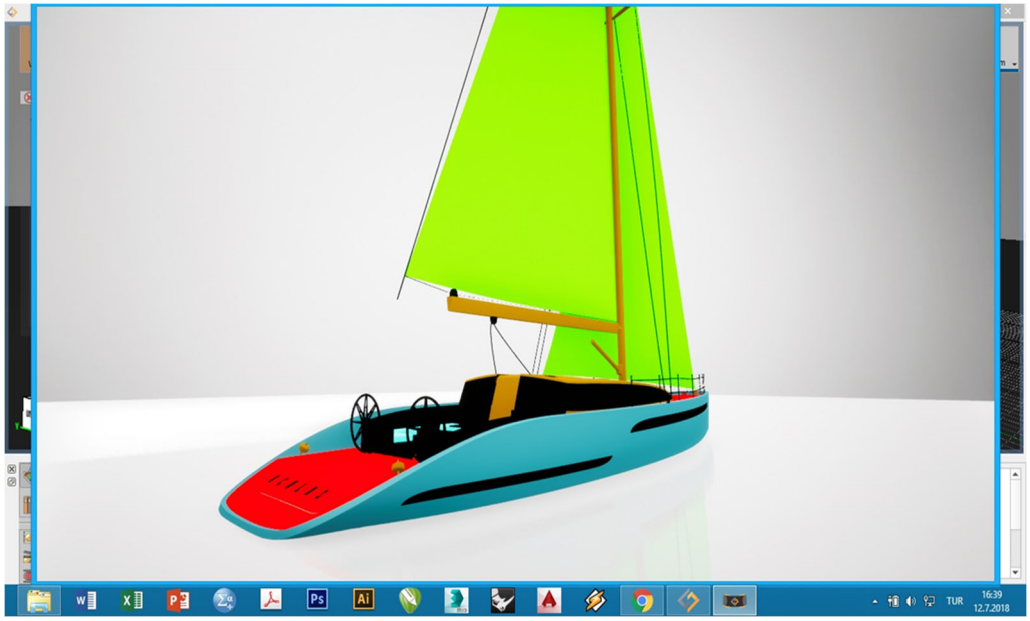


Figure 5.33 : An example of viewing a CAD model in the VR scene with the desktop mode of SimLab Composer 8.0.

— Potential users think that VR is a complex system in itself and requires a large space, too many steps including installation of its setup and data transfer every time to be taken to experience the design. Therefore, it consumes time. They also think that there is need for a person to keep an eye on the user while using it. Besides, they think that VR may not be hygienic for multiple users. Also, it requires learning. For these reasons, it was decided to employ the researcher both: an operator who is responsible for installing and running the VR system properly, and responsible for its being used easily and hygienically; and as an educator who will meet the learning need for VR.

— It was evaluated that in terms of managing the entire design process by just one student, the "smart electric minibus" to be designed is already a very complex product that includes mechanisms, many fasteners, production details, electronic parts, and displays, and also it was evaluated that preparing a VR scene to be used in jury sessions will also add an extra workload for students. For these reasons, it was decided to conduct the project process in the course as a group project.

The summary of the decisions taken for planning the general framework of the in-studio study and the reasons behind these decisions are presented in Table 5.10.

Table 5.10 : Decisions taken for planning the general framework of the in-studio study and reasons behind.

Decision(s)	Reason(s)
• The 3rd year industrial design studio course "EUT 320E Industrial Product Design III" with the project issue "Smart Electric Minibus Design for Anadolu Isuzu" is selected to conduct the in-studio study.	• VR is a computer-based technology, and in the educational planning of ITU Department of Industrial Design, students are not allowed for computer use in the project processes of the 1st and 2nd-grade industrial design studio courses. • VR is a CAD-based technology, and in ITU Department of Industrial Design, the compulsory courses in which students are taught CAD software are included in the 2nd-grade curriculum. • Potential users think that VR will be useless when designing small products.
• The project process in the course will be conducted as a group project.	• In terms of managing the entire design process by just one student, the "smart electric minibus" to be designed is already a very complex product that includes mechanisms, many fasteners, production details, electronic parts, and displays. • Preparing a VR scene to be used in jury sessions will also add an extra workload for students.
• The use of VR by students for design presentation purposes will be made mandatory in the jury sessions after the concept selection phase. • VR will be available for use during the studio hours of the course.	• VR can be employed in the design process in industrial education as a(n) empathy development tool, inspiration tool, design visualization tool, presentation tool, and design evaluation tool. However, potential users think that VR is a good tool for presentations and will be the most useful for design evaluation. • Potential users think that VR cannot be employed in the early stages of the design process because it is a CAD-based technology, and the literature states that, in a generic design process, CAD and CAD-based tools are mainly used after the concept selection phase.

Table 5.10 (continued) : Decisions taken for planning the general framework of the in-studio study and reasons behind.

Decision(s)	Reason(s)
• HTC Vive will be employed in the research as VR equipment.	• HTC Vive is the only VR headset allowing to experience the design at room-scale among those can run with PCs. Also, it has the best tracking performance in mobility.
• SimLab Composer 8.0 will be used as the intermediary software enabling to experience CAD models in VR scenes.	• Potential users think that VR software may not be compatible with all computer configurations and CAD software used by students. • SimLab Composer 8.0 o offers 2 years free license with full features for 1PC to all university students and instructors. o is compatible with almost all CAD software commonly used by industrial design students and can be run as integrated with CAD software and embedded in its interface. o uses a human figure to set the starting position of the camera in the VR scene. Thus, the camera positioning in the VR scene can be done in a more naturalistic way. o has a desktop VR mode that enables students to test the prepared VR scene by viewing it on the computer screen without the need for connection with a VR headset.
• During the course, the researcher will work both: as an operator who is responsible for installing and running the VR system properly, and responsible for its being used easily and hygienically; and as an educator who will meet the learning need for VR.	• Potential users think that o VR is a complex system in itself and requires a large space, too many steps including the installation of its setup and data transfer every time to be taken to experience the design. Therefore, it consumes time. o There is a need for a person to keep an eye on the user while using VR. o VR may not be hygienic for multiple users. o VR requires learning.

5.2.2 Description of the selected industrial design studio course

The course "EUT 320E Industrial Product Design III" in the curriculum of ITU Industrial Product Design Department is a must course for the sixth semester. According to the official course catalog form of the course, this course involves;

— Creating innovative and critical concepts;

— Verbal, written and visual expression of these concepts;

— The issues of cultural identity;

— The environmental and ecological factors;

— The social responsibility;

— Teamwork;

— Communication with different disciplines;

— Cost analysis and produce ability;

— Ability to create a product family;

— Developing a product sales scenario;

— Considering the factors as marketing and packaging;

— Ability to develop scenarios for use.

	Program Outcomes	Level of Contribution		
		1	2	3
1	Observation, problem identification and decomposition knowledge and skills			X
2	Skills in research, information gathering and analysis methods in every stage of the design process.			X
3	Knowledge and skills in systematic application of creative problem solving methods			X
4	Skills of conceiving design concepts for innovative product and services			X
5	Skills of creating and developing sufficient number of alternative design concepts in a given time period.			X
6	Knowledge and skills for employing manual and computer-aided visualization of design concepts		X	
7	Knowledge and skills for 3D and 4D models, and prototyping.		X	
8	Knowledge and skills in verbal and written communication of ideas and concepts.			X
9	Research skills for deep understanding of users and their related processes			X
10	Knowledge and skills for understanding physical, psychological, ergonomics, cultural and social needs of users.			X
11	Skills for creating and developing meaningful product forms			X
12	Knowledge and skills in evaluating, choosing and using materials.			X
13	Knowledge in modern manufacturing methods.		X	
14	Knowledge and skills in evaluating and using information technologies		X	
15	Knowledge and skills for developing creative design solutions on the basis new technology			X
16	Knowledge and skills in understanding and assessing company strategies and culture		X	
17	Planning and managerial skills for industrial design projects			X
18	Multidisciplinary teamwork skills			X
19	Knowledge and skills in understanding market dynamics and trends		X	
20	Entrepreneurial and leadership skills in design		X	
21	Knowledge and skills for developing analytical approaches to natural and artificial environment			X
22	Knowledge about the social, cultural economic and environmental context of industrial design			X
23	Skills for observing, capturing and evaluating the changing life styles, and their reflections			X
24	Apprehensive skills for visual aesthetic values		X	
25	Developing attitudes for listening, inquiring, understanding, being open for critique and self-development and renewal			X
26	Skills for self-learning		X	
27	Skills for transforming local cultural values into design inputs.		X	
28	Knowledge about professional ethics in industrial design		X	
29	Knowledge about the historical development of industrial design in Turkey and the World.	X		
30	Knowledge about the legal rights and responsibilities of industrial designers	X		
31	Effective use of professional design terminology			X
32	Knowledge about the role of industrial design for the social and economic development of Turkey	X		

1: Little, 2. Partial, 3. Full

Figure 5.34 : Relationship between the course and Industrial Product Design Program, taken from (URL-9).

The objectives of the course are;

— to support the students to create innovative and critical concepts and to express them verbally and visually,
— to process design projects carefully including advanced subjects as environment, ecology and sustainability,
— to process design projects within a design team in communication with different disciplines,
— to process design projects informing students about developing detailed scenarios of use and creating a product family.

In this course, computer use is compulsory, and the relationship between the learning outcomes of the course and the program outcomes is as presented in Figure 5.34.

The full catalog form of this course is presented in Appendix E.

This course was conducted in the 2017-2018 spring semester by Prof. Dr. Şebnem Timur, Res. Asst. Seda Duman, Res. Asst. İffet Pala Ercan, and Res. Asst. Ahmet Hamurcu, the researcher of this study at the same time. The project process was carried out in cooperation with the firm "Anadolu Isuzu". Görkem Erdoğan the R&D team leader of Anadolu Isuzu and Sadık Gelirli a senior industrial product designer of Anadolu Isuzu contributed both to the preparation of the project brief as representatives of the firm and the jury sessions as invited jury members.

5.2.3 Brief of the selected project

A project brief was prepared by the instructors together with the representatives of the firm "Anadolu Isuzu" to be handed out to students in the first studio-hour. The full text of this project brief is presented in Appendix C. According to this project brief, the project issue was defined as developing design proposals for a smart electric minibus that will be operated in urban areas and provide citizens' rapid transportation. It was expected that these proposals should include smart solutions and ideas that improve the users' transportation experience and contain:

- an exterior solution,
- an interior solution,
- a user experience scenario,
- a service and payment system,
- an integrated solution within the concept of smart cities.

Before the concept development phase, students were required to carry out desk research and user research and present their results. How they were asked to conduct these studies can be seen in detail in the project brief presented in Appendix C. In addition, as this project was conducted as a group project, they were asked to keep a diary of their individual and/or group work daily to be used as an evaluation mechanism for individual assessment. At the end of the project process, they were asked to submit

1. *Design Drawings*, including
    - Design concept based on user research
    - Exterior and interior solution
    - User experience scenario
    - Service and payment system
2. *Technical Drawings*, including
    - Scaled orthographic views with detailed dimensions
    - Sectional views
    - Detail drawings
    - Exploded perspective drawings
3. *3D Virtual Model (3D print ready) and 1/10 scale physical model*
4. *Digital documentation of the project in PDF format*
5. *Personal diaries*

5.2.4 Integration of the research process into the project process

This research was carried out with both a structured and an unstructured intervention to the natural flow of the course by adding the use of VR technology for different purposes to the actual processes of the selected design studio course. The structured intervention was defined as making the use of VR by students mandatory in the jury sessions, whereas the unstructured intervention was defined as making VR available for voluntary use in other practices within the course. By making the use of VR mandatory in the jury sessions, how it can be integrated into the jury practices of industrial design education was researched, and by observing the voluntary use of it, it was tried to get clues about how it can be integrated into the other practices of industrial design education. For these purposes, action research methodology was

employed. This action research process was conducted by being integrated into the project process (Table 5.11) and in a way that would not break the project schedule. Figure 5.35 shows how the research process was integrated into the project process and the schedule.

Table 5.11 : The project schedule presented in the project brief.

Week	Date	Studio Content
1	06.02	– Introduction of the project subject – Distribution of the Design Brief on NINOVA – Forming of the project groups – Announcing of the research papers demand as a homework
	09.02	– Confirmation of the groups – Group Research Work
2	13.02	– Technical presentation by ISUZU – **Group Presentations I: Desk Research Findings and Research Reports**
	16.02	– Studio Work
3	20.02	– Studio Work
	23.02	– Studio Work
4	27.02	– **Group Presentations II: User Research Findings and Research Reports**
	02.03	– **Individual Concept Proposals**
5	06.03	– Concept Development
	09.03	– Concept Development
6	13.03	– **Preliminary Jury 1** Concepts proposed by each group member
	16.03	– Design Development
7	20.03	– Design Development
	23.03	– Design Development
8	27.03	**Mid Term Break / No class**
	30.03	**Mid Term Break / No class**
9	03.04	– Design Development
	06.04	– **Preliminary Jury 2** Exterior and interior solutions
10	10.04	– Design Development and Refinement
	13.04	– Design Development and Refinement
11	17.04	– Design Development and Refinement
	20.04	– Design Development and Refinement
12	24.04	– Design Development and Refinement
	27.04	– Design Development and Refinement
13	01.05	**Labor Day / No class**
	04.05	– **Preliminary Jury 3** Final review
14	08.05	– Presentation and Prototyping (Virtual & Physical)
	11.05	– Presentation and Prototyping (Virtual & Physical)
15	15.05	– Presentation and Prototyping (Virtual & Physical)
	18.05	– Presentation and Prototyping (Virtual & Physical)

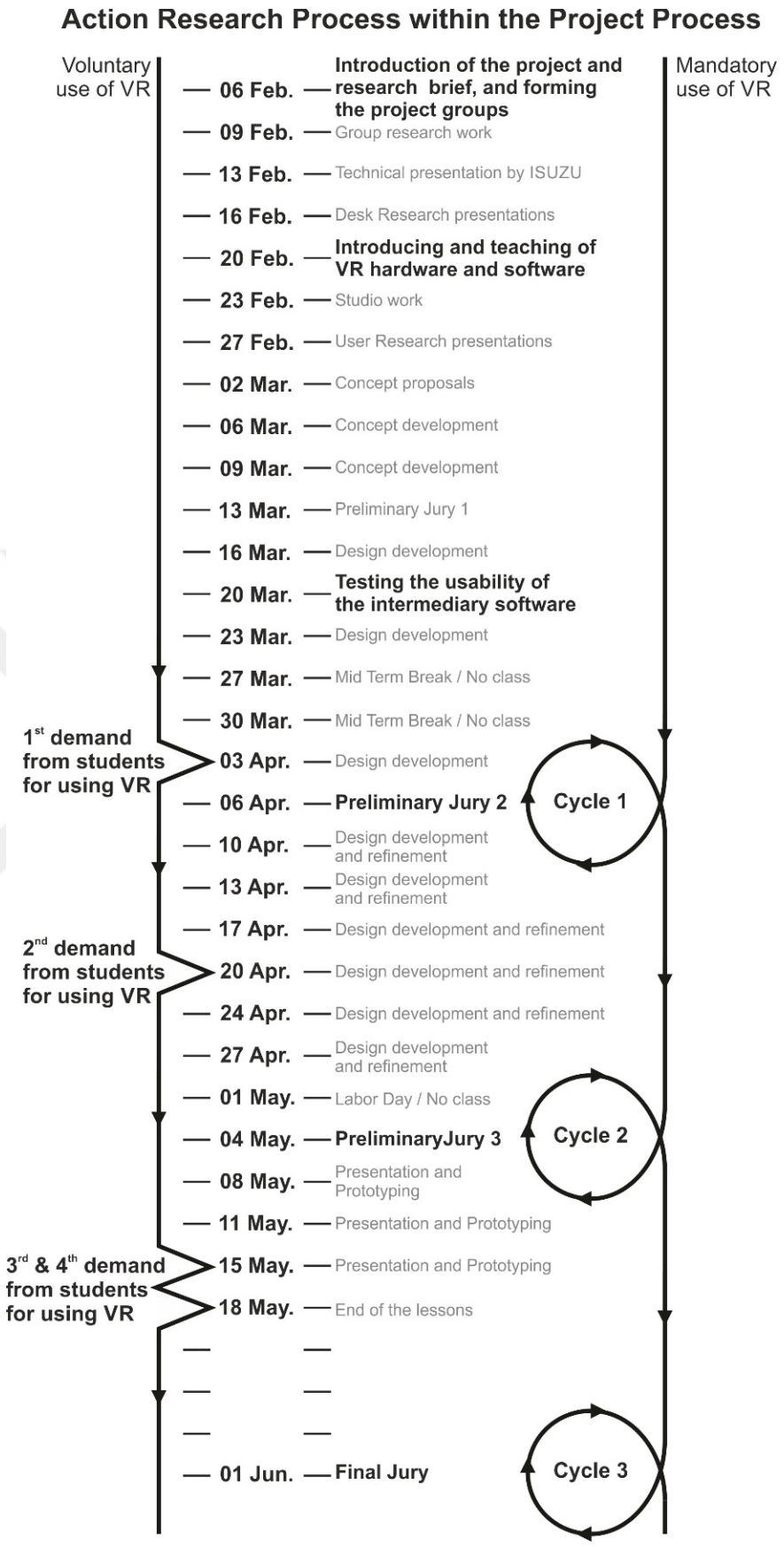


Figure 5.35 : Integration of the action research process into the project process.

According to this merged process, in the first lesson on February 6, 2018, both the project brief and the research brief were introduced together. Regarding the research, it was announced to students that

- they were expected to use VR for design presentation purposes in the jury sessions.
- they were free whether to use it in other parts of the course,
- whether they use VR during the course or not will not affect their grading positively or negatively,
- their software and equipment needs in the studio-hours and the jury sessions, and learning needs that are required to use them will be met by the researcher who is one of the instructors of the course,
- VR equipment with software to be used will be available for students during studio hours throughout the semester.
- they were free not to participate in the research to be conducted during the course or to withdraw from it at any time without having to give a reason for withdrawing.

In the first lesson, also, the project groups of students were formed. It was decided to divide the 30 students enrolled in the course into 10 groups of 3 each. However, it was considered that since VR is CAD-based technology, the use of it will be highly correlated with students' CAD skills. For this reason, while forming the project groups, it was tried to distribute the students with high CAD skills to the groups equally. In order to do this distribution, the grades of students in the compulsory CAD courses taken in the second year were used. 10 students who got the highest grades in these courses were determined as the first members of the groups, and it was announced that these members were assigned to the groups as the main members who were primarily responsible for the CAD works of the groups. These students also determined other members of the groups themselves. However, in the add-drop week of the course (the first week of the course), two students who were not the first member of the groups withdrew from the course.[12] Thus, the project groups were shaped as 8 groups of 3

[12] Reasons for these students withdrawing from the course were not related to the research to be conducted during the course.

each and 2 groups of 2 each. The age and gender distributions of the group members are presented in Table 5.12.

Table 5.12 : Age and gender distributions of the project groups.

Group	Member	Age	Gender	Group	Member	Age	Gender
1	1.1	22	Female	6	6.1	21	Female
	1.2	22	Female		6.2	23	Female
	1.3	23	Female		6.3	21	Female
2	2.1	21	Female	7	7.1	25	Male
	2.2	20	Female		7.2	22	Female
	2.3	24	Female		7.3	21	Female
3	3.1	22	Male	8	8.1	24	Male
	3.2	22	Female		8.2	22	Female
	3.3	23	Female		8.3	22	Female
4	4.1	22	Male	9	9.1	25	Male
	4.2	23	Female		9.2	23	Female
	4.3	22	Female				
5	5.1	22	Male	10	10.1	21	Female
	5.2	23	Female		10.2	23	Female
	5.3	21	Female				

In the lesson on February 20, 2018, the VR equipment and software to be used within this research were introduced and taught to students by the researcher with a three-hour presentation and demonstration (Figure 5.36). Before this lesson, how to download and install SimLab Composer 8.0 and how to get 2 years free license with full features were shown to students at the end of the previous lesson on February 16, 2018, and they were asked to install the software on their laptops with a free license and come to class as being ready to use the software for this lesson. So, in this lesson, students did not spend their time downloading, installing, and licensing the software. In this lesson, students were taught

- Interface of the software,
- How to import a CAD model into the software,
- How to use the basic commands of the software regarding transforming, moving, rotating the CAD model, and assigning a material to it,
- How to use the CAD integration feature of the software,
- How to use the human figure of the software to set the starting position of the VR camera and the proportion between viewer and the CAD model,
- How to use the desktop VR mode of the software,
- How to experience a CAD scene with an HTC Vive VR headset as a VR scene,

— What kinds of mobile phones can be converted into VR glasses with low-cost mobile VR equipment such as Google Cardboard and VR Box, and how to use such mobile VR system to experience a CAD scene as a VR scene with the help of “SimLab VR viewer”, which is the mobile app of SimLab software

by demonstrating.

Figure 5.36 : Introducing and teaching the VR equipment and software to be used.

At the end of this session, in other words, after teaching by demonstrating how to use VR equipment and software, students were handed out an Informed Consent Form (ICF) prepared beforehand in accordance with the ICF template of ITU Social and Humanities Sciences Committee of Human Research Ethics, and they were asked to

sign and submit it back if they accepted to participate in the research to be conducted within the course throughout the semester. All students signed the consent form.

In the lesson on 23 February 2018, the VR setup to be used (the room-scale setup of HTC Vive) was installed at the beginning of the lesson, and it was announced that students who want to try it could try it as they want without any permission. In this way, it was thought that the possible tensions on students would be reduced by gaining familiarity with the technology they would use. Also it was announced that no records would be taken for this trial session so that students could try VR technology comfortably as they wish without hesitation.

In the lesson on March 20, 2018, the usability of the taught software SimLab Composer 8.0 was tested by getting the first-selected members of the groups to use it. The purpose of this test was to question whether the students who were primarily responsible for the CAD works of the groups will have difficulty in using the selected intermediary software. To evaluate the usability level of the software based on a measurement, the System Usability Scale (SUS) was used. SUS is a "quick and dirty" survey tool based on a questionnaire developed by John Brooke (from DEC) in 1986 to assess the usability of a(n) interface, product, or service. Although, there are several alternatives with higher reliability scores than SUS in the literature (Table 5.13), Bangor et al. (2008) state that four major reasons make the SUS survey a good choice for general usability studies:

> The survey is technology agnostic, making it flexible enough to assess a wide range of interface technologies, from interactive voice response systems (IVRs) and novel hardware platforms to the more traditional computer interfaces and Web sites. Second, the survey is relatively quick and easy to use by both study participants and administrators. Third, the survey provides a single score on a scale that is easily understood by the wide range of people (from project managers to computer programmers) who are typically involved in the development of products and services and who may have little or no experience in human factors and usability. Finally, the survey is nonproprietary, making it a cost effective tool as well. (Bangor et al., 2008, p. 574)

Table 5.13 : Summary of examined usability surveys, taken from (Bangor et al., 2008, p. 575).

Survey Name	Abbreviation	Developer	Survey Length (Questions)	Availability	Interface Measured	Reliability
After Scenario Questionnaire	ASQ	IBM	3	Nonproprietary	Any	0.93[a]
Computer System Usability Questionnaire	CSUQ	IBM	19	Nonproprietary	Computer based	0.95[b]
Poststudy System Usability Questionnaire	PSSUQ	IBM	19	Nonproprietary	Computer based	0.96[c]
Software Usability Measurement Inventory	SUMP	HFRC	50	Proprietary	Software	0.89[d]
System Usability Scale	SUS	DEC	10	Nonproprietary	Any	0.85[e]
Usefulness, Satisfaction and Ease of Use	USE	Lund	30	Nonproprietary	Any	Unreported[f]
Web Site Analysis and Measurement Inventory	WAMMI	HFRG	20	Proprietary	Web based	0.96[g]

[a]Lewis (1995), [b]Lewis (2002), [c]Kirakowski & Corbett (1993), [d]Igbaria & Nachman (1990), [e]Kirakowski (1994), [f]Lund (2001), [g]Kirakowski et al. (1998).

Also, it is reported by Usability.gov (n.d.) that SUS can be used on small sample sizes with reliable results. For these reasons, SUS was selected to test the usability level of the software SimLab Composer 8.0.

SUS consists of 10 scale items. These items were used in this study by just replacing the word "system" in the statements with "software" that refers to SimLab Composer 8.0 (Table 5.14).

As mentioned before, the usability testing of the intermediary software “SimLab Composer 8.0 was conducted with the first-selected members of the groups (total of 10 students) by using SUS in the lesson on March 20, 2018. First, these members were asked whether they try to use SimLab Composer 8.0 to make exercise or practice in the one-month period lasted since the lesson this software was taught. All of them reported that they had not tried to use the software for any exercise or practice purposes. Then, they were given a raw CAD model of some office furniture and equipment, and asked respectively

— to import it into SimLab Composer 8.0,

— to adjust its position in the CAD environment,

— to assign some materials to it,

— to set its proportion and the starting point of the VR camera by using the human figure of the software,

— to test whether the VR scene runs correctly by using the desktop VR mode of the software.

Table 5.14 : The original SUS items and how they were modified for measuring the usability level of the intermediary software.

	Original SUS Items	Modified SUS Items
1	I think that I would like to use this **system** frequently.	I think that I would like to use this **software** frequently.
2	I found the **system** unnecessarily complex.	I found the **software** unnecessarily complex.
3	I thought the **system** was easy to use.	I thought the **software** was easy to use.
4	I think that I would need the support of a technical person to be able to use this **system**.	I think that I would need the support of a technical person to be able to use this **software**.
5	I found that the various functions in this **system** were well integrated.	I found that the various functions in this **software** were well integrated.
6	I thought that there was too much inconsistency in this **system**.	I thought that there was too much inconsistency in this **software**.
7	I would imagine that most people would learn to use this **system** very quickly.	I would imagine that most people would learn to use this **software** very quickly.
8	I found the **system** very cumbersome to use.	I found the **software** very cumbersome to use.
9	I felt very confident using the **system**.	I felt very confident using the **software**.
10	I needed to learn a lot of things before I could get going with this **system**.	I needed to learn a lot of things before I could get going with this **software**.

They tried to perform the given tasks by recalling what they learned (Figure 5.37). After this recalling session, they were asked to fill out the 10-item SUS questionnaire with a 5-point Likert scale ranging from strongly disagree to strongly agree (1 = “strongly disagree” – 5 = “strongly agree”).

The results of SUS studies are interpreted based on a SUS score calculated by following the steps described by Sauro (2011) as follows:

1. Subtract one from the participant response for odd-numbered items (1,3,5,7, 9),
2. Subtract the participant responses from 5 for even-numbered items (2,4,6,8 10)
3. Add up the converted responses for each participant,

4. Multiply that total by 2.5 to convert the range of possible values from 0 to 100.

According to this formulation, the SUS score of SimLab Composer 8.0 was calculated as 69.75. How the percentile ranks associate with SUS scores and letter grades is described by Sauro (2011) with the chart presented in Figure 5.38. Based on this chart, he states that "a SUS score above 68 would be considered above average and anything below 68 is below average". On the other hand, according to Thomas (n.d.), if the SUS score of any software is 68 or thereabouts, it means the usability of the software is OK but could improve. Based on these explanations, the usability level of SimLab Composer 8.0 was accepted as sufficient to continue the research with this software.

The action research processes regarding the mandatory use of VR in the jury sessions and the voluntary use of it in other practices are presented separately in the following sections.

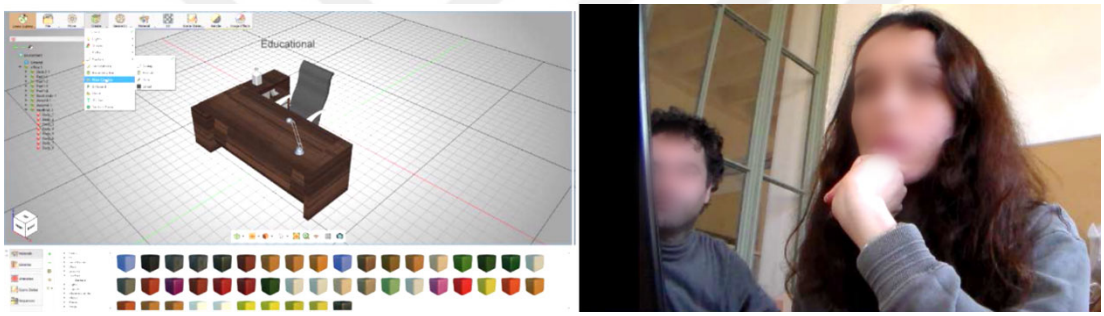


Figure 5.37 : A photo taken while a student was performing the given task and the screenshot of the computer screen at that moment.

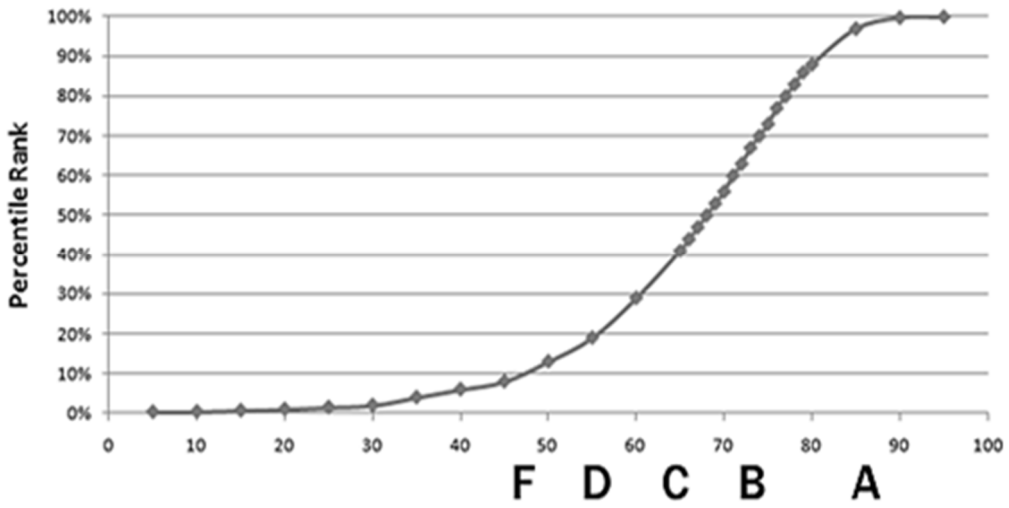


Figure 5.38 : Associating SUS scores with percentile rank and letter grades, taken from (Sauro, 2011).

5.2.5 Mandatory use of VR in the jury sessions

This part of the research focuses on the integration of VR technology into the jury practices of industrial design education in the educational setting of an industrial design studio course and aims to get an understanding of how this technology can be integrated into industrial design education in this way.

As mentioned before, since potential users think that VR cannot be employed in the early stages of the design process because it is a CAD-based technology and the literature states that in a generic design process CAD and CAD-based tools are generally used after the concept selection phase, the jury sessions that take place after the concept development phase in the project schedule (the preliminary jury 2, the preliminary jury 3, and the final jury) are decided to be carried out as the cycles of this part of the research. Due to being conducted at the end of the concept development phase of the project process with the purpose of helping the concept selection of each group, the first preliminary jury was excluded. So, the second preliminary jury is the first cycle, whereas following jury sessions – the third preliminary jury and the final jury – are, respectively, the second and the third cycles. In the following sections, these cycles are presented separately in detail.

5.2.5.1 The 2nd preliminary jury session: the 1st cycle of mandatory use

Plan: planning the 2nd preliminary jury session

Karadoğaner and Börekçi (2018) state that, in general, industrial design students use "writings, photos, sketches, mock-ups, 3D models, realistic visuals" as design representation tools to present and explain product aspects such as "usage scenario, form, size, mechanism, detail, inner parts, technology, user interface, usage context/environment, material, production, function, user experience, user interaction". These design representations are usually presented in the jury sessions via three main channels:

- Design sheets (generally A3 size papers),
- Physical models (at various levels of fidelity level), and
- Digital presentation tools (such as PowerPoint and video player)

In their further study, Karadoğaner & Börekçi (2020) depict how industrial design students use design representation tools to present and explain which product aspects

as in Table 5.15. As this study has shown, there are already resident patterns of use types for design representations routinely chosen by students in the jury sessions of industrial design education. However, in this study, no pattern related to "user experience", "user interaction", "emotion", and "maintenance" could be depicted.

Table 5.15 : Design representation tool use of industrial design students to present and explain product aspects, taken from (Karadoğaner, 2020, p. 122).

Product aspects	Design representation tools used to explain product aspects
usage scenario*	mock-up, mock-up + render + graphic/photo, mock-up + 3D-model/render, mock-up + sketching + writing, mock-up + sketching/graphic, 3D-model, 3D-model + sketching, render, render + graphic/writing, render + graphic + writing, render + photo - sketching, sketching, sketching * writing, photo, video
user experience*	*limited information to conclude*
user interaction*	*limited information to conclude*
emotion*	*limited information to conclude*
user interface	graphic, graphic + mock-up/sketching, mock-up, render + graphic, sketching, sketching + writing
features/function	3D-model, 3D-model + render, render, render + mock-up + graphic/sketching, render + graphic * photo/sketching, render + writing, mock-up, mock-up + graphic, graphic + graphic + writing, sketching, sketching + writing
part/parts	3D-model, 3D-model + render/mock-up, 3D-model + sketching + writing, render, render + writing/mock-up, render + mock-up + writing sketching, sketching + writing
physical ergonomics	mock-up, mock-up + 3D-model/sketching, sketching, render, sketching, writing, render + graphic + mock-up
aesthetic/form	3D-model, 3D-model + render/mock-up/sketching, render, render + mock-up/sketching, mock-up, mock-up + sketching
size	mock-up, mock-up + 3D-model/render/sketching, mock-up + render + photo, render + graphic
material/color	render, render + mock-up/sketching, render + photo, sketching, sketching + writing
product configuration	render, 3D-model + render + mock-up
context/environment	render - photo, render + graphic + photo, photo, writing
mechanism	3D-model, 3D-model + mock-up/sketching, mock-up, mock-up + sketching/video, sketching, sketching * writing
detail	3D-model, 3D-model + render/mock-up, render, render + mock-up, mock-up, mock-up + sketching/video, sketching, sketching + writing
technical standards	*limited information to conclude*
assembly/set-up	*limited information to conclude*
inner parts	3D-model, 3D-model + render/writing, render, render + writing
technology	3D-model, 3D-model + render/writing, 3D-model + render + writing, render, render + writing, sketching + writing
maintenance	*limited information to conclude*

* *Although these considerations are not directly related to product aspects but give direction to the development of product aspects, they are included as product aspects.*

On the other hand, the study of Chen (2016) on the difficulty levels of tasks performed by students throughout the design process in industrial design courses shows that "design presentation" is the most difficult one in the process after the concept development phase (Table 5.16).

Table 5.16 : Percentages of the most difficult design tasks as identified by students by course year, gender, and school; results of Chi square tests, taken from (Chen, 2016, p. 472).

Design tasks	Course year		Gender		School			Total
	2nd	3rd	Female	Male	U1	U2	U3	
Design research	34.1	34.7	32.8	37.0	21.4	37.8	40.0	34.4
Concept generation	89.8	76.2	81.9	83.6	73.8	85.8	80.0	82.5
Design decision	34.1	28.7	33.6	27.4	50.0	25.2	30.0	31.2
Design presentation	39.8	41.6	40.5	41.1	54.8	36.2	40.0	40.7
Design documentation	15.9	7.9	14.7	6.8	2.4	15.0	10.0	11.6
X^2	2.676		3.052		16.361			
df	4		4		8			
p value	0.613		0.549		0.037*			

Percentage = number of responses/number of subjects
* p< 0.05

When being planned the first cycle, in accordance with these studies, it was thought that students' design representations could be supported by VR technology, and in this way, they would have less difficulty in presenting their products' aspects, especially the aspects that have no pattern detected in the study of Karadoğaner & Börekçi (2020) such as “user experience”, “user interaction”, and “emotion”. In other words, it was thought that VR would be used as a supporting design representation tool that would support the design sheets (digital or not) and mock-ups which can be considered as commonly used tools by students in their presentations. Therefore, based on the eight phases of the design jury session by Roberts (2004) (presented before in Table 2.5), the jury session where VR would be employed was anticipated to consist of three generic stages below.

1. Students will explain their design details and decisions behind them by referring to the representations of the designed product, such as its drawings and renderings on their design sheets, and its physical model(s).

2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information, if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets and/or (a) physical model(s), jurors can experience the design individually by using the VR headset for better understanding and evaluation.

With these thoughts, it was announced to students that they were free to use any set of design representation tools they wanted while making their design presentations, but the VR scenes of their designs had to be included in this set. In other words, they were not given a submission list regarding the preliminary jury, however, they were announced that they had to submit the VR scenes of their designs before the preliminary jury session with the other design representations they would use.

Act: performing the 2nd preliminary jury session by using VR

Throughout the semester, studio 217B of ITU Architecture Faculty was used as the course place. The regular seating plan of studio 217B is presented in Figure 5.39. This seating plan was changed as in Figure 5.40 immediately before the jury session to be performed using VR. This figure also shows the positions of two video cameras used for recording the jury session. This jury session was recorded with two video cameras and a voice recorder.

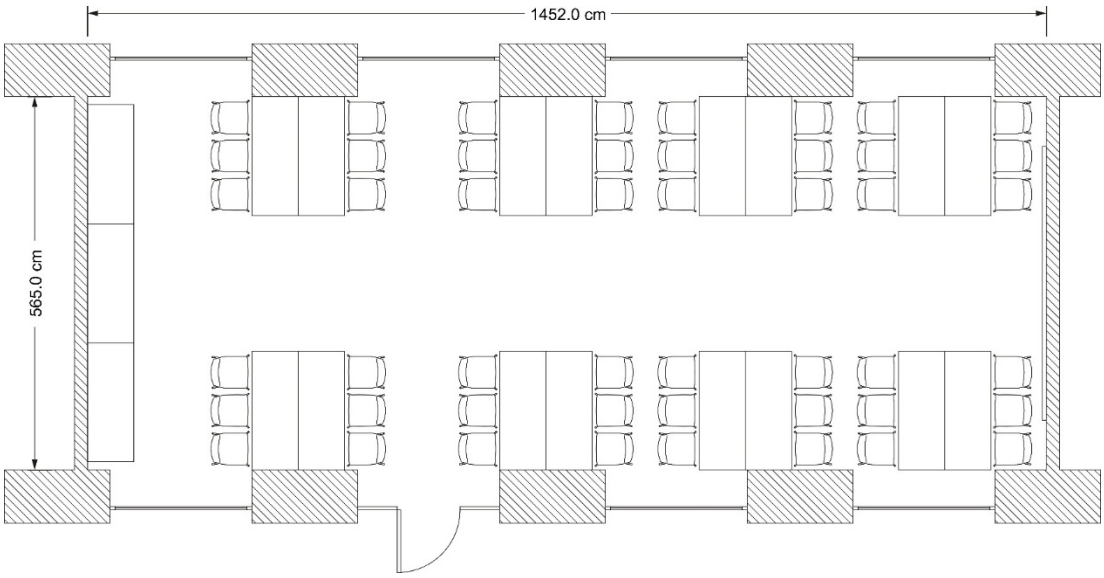


Figure 5.39 : The regular seating plan of studio 217B.

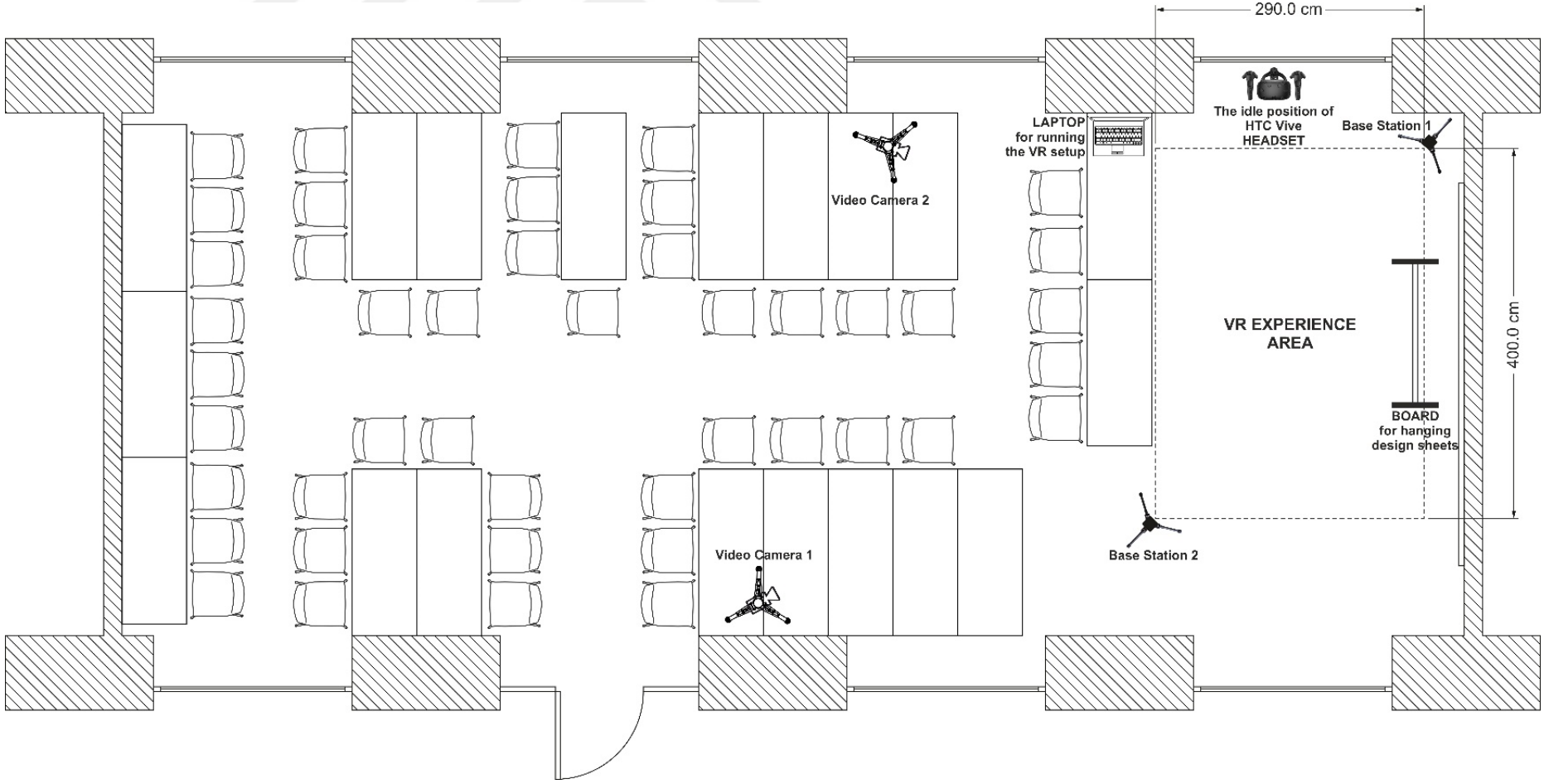


Figure 5.40 : Rearranging the seating plan for the 2nd preliminary jury session.

Additionally, three chairs were used as a barrier to prevent students or others from tripping over the cables of Base Station 2 (Figure 5.41).

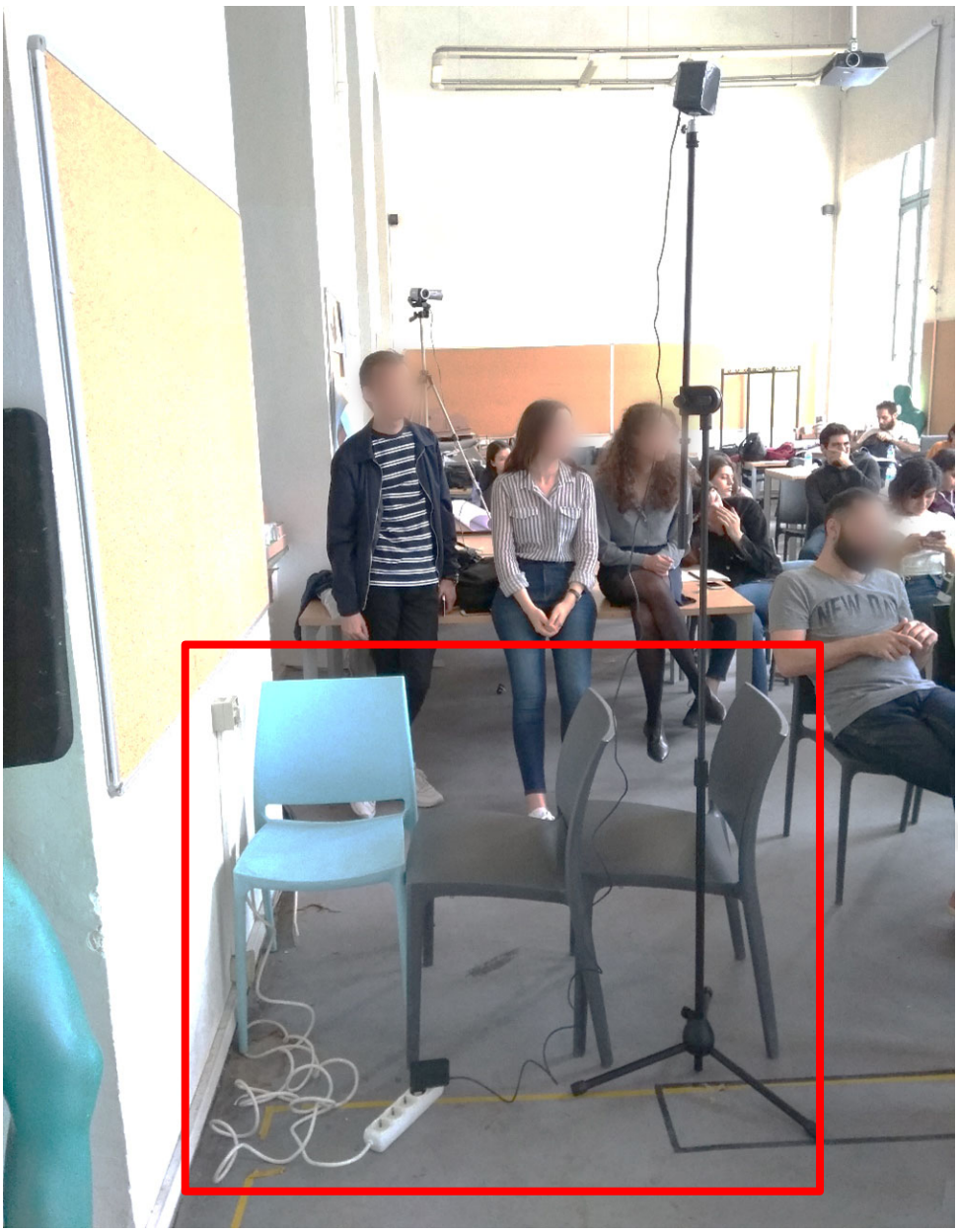


Figure 5.41 : The use of three chairs as a barrier to prevent students or others from tripping over the cables of Base Station 2.

This preliminary jury was performed on April 6, 2018. It lasted approximately 4 hours except for the break times. Each group's jury session lasted an average of 24 minutes. The exact times are presented in the following section.

Just before the first group's presentation, a brief training was given to the jurors on how to use the VR headset and its control sticks. In this training, the VR scene of the first group was used.

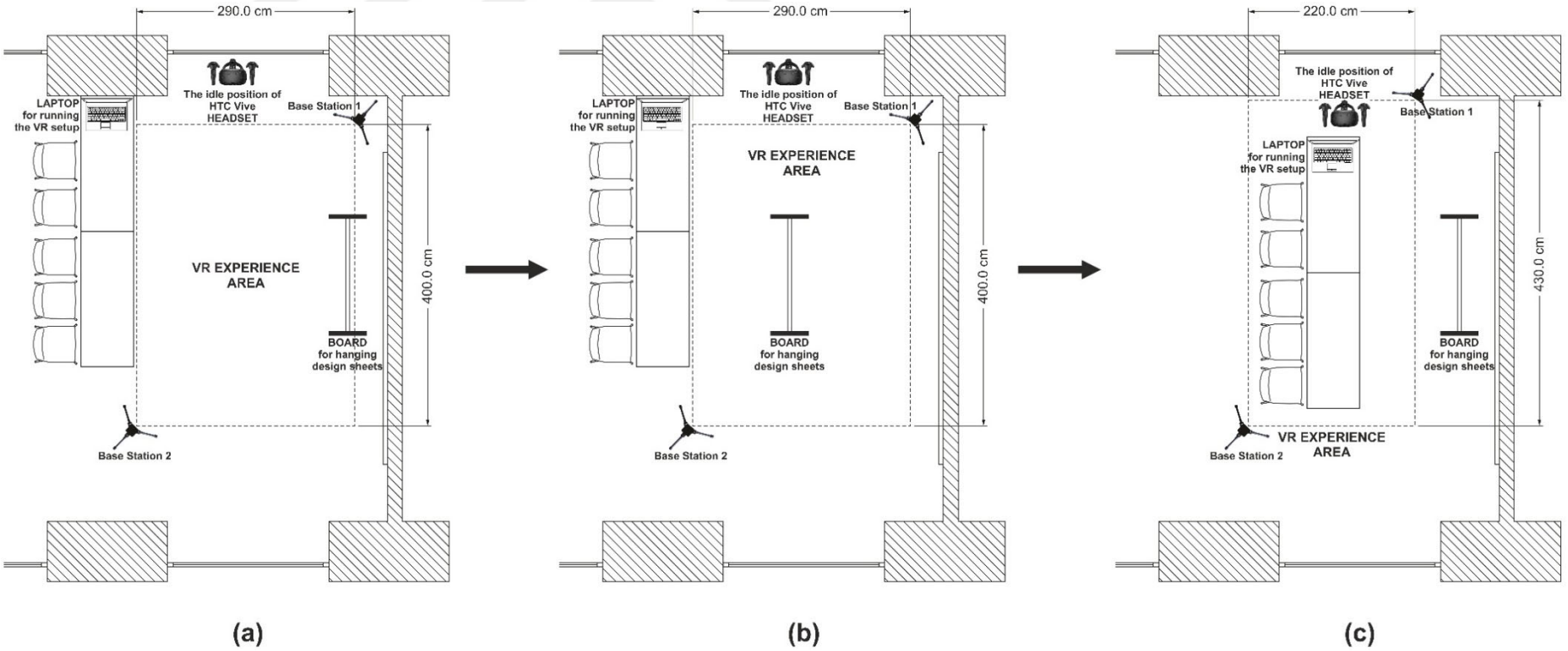
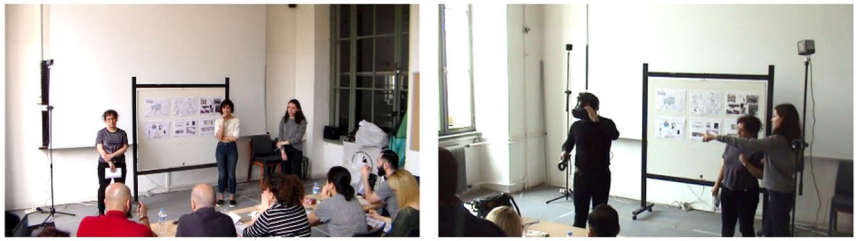


Figure 5.42 : Changes made in the jury setup layout during the jury session: (a) is the proposed layout, (b) and (c) are the changes respectively made in the layout in line with the juror's demands.

(a) The proposed jury setup and way of VR use within it



(a.1) (a.2)

(b) Bringing closer the board on which the design sheets were hung

(b.1) (b.2) (b.3)

(c) Trying whether the jurors can experience the VR scenes without leaving their chairs by reorganizing the jury setup

(c.1) (c.2)

(d) The reached jury setup and way of VR use within it

(d.1) (d.2)

Figure 5.43 : Photos showing the proposed jury setup with VR and the changes made in it during the jury session.

In the jury session, although the researcher was one of the instructors of the course, he took place as an operator – not as a jury member – who is only responsible for installing and running the VR system properly, and also responsible for its being used easily.

Observe: questioning what happened in the 2nd preliminary jury session

(a) Observations

Observation 1. Although it was announced to the students that they are free to benefit from any kind of design representation for presenting their design ideas, none of the project groups made, submitted, and presented any physical mock-ups and/or models for/in this preliminary jury. However, unlike other project groups, Group 7, in their presentation, used a video animation – created in Maya – showing what a user sees while s/he is getting on the minibus, looking around in the minibus, walking toward the back of the minibus, and getting off from the back door.

Observation 2. The VR scenes (Figure 5.44) of the groups had not contained user-product interactions such as opening and closing the doors of the vehicle and turning on a light by pressing a button but they contained the basic VR interactions such as walking, jumping, and moving the head for the 360-degree experience of the virtual model.

Observation 3. The space left blank for the VR experience (Figure 5.42 a, and Figure 5.43 a.1) caused the jury members to stay away from the design sheets, thus having difficulty seeing them clearly. Hence, while the second group's presentation was going on, the jurors requested to bring closer the board on which the design sheets were hung. Therefore, the board was positioned closer to the jury members (Figure 5.42 b, and Figure 5.43 b).

Observation 4. It was observed that the jury members were reluctant to get up from their chairs each time to experience the VR scenes. For this reason, at the beginning of the presentation of the third group, the jury setup layout was rearranged as in Figure 5.42 c so that they could experience the VR scenes without leaving their chairs (Figure 5.43 c). However, in this setting, the VR headset did not work properly when they tried to use it by sitting in their chairs. So, they continued to use it by standing in the reserved area for the VR experience till the end of the jury session without rearranging the layout.

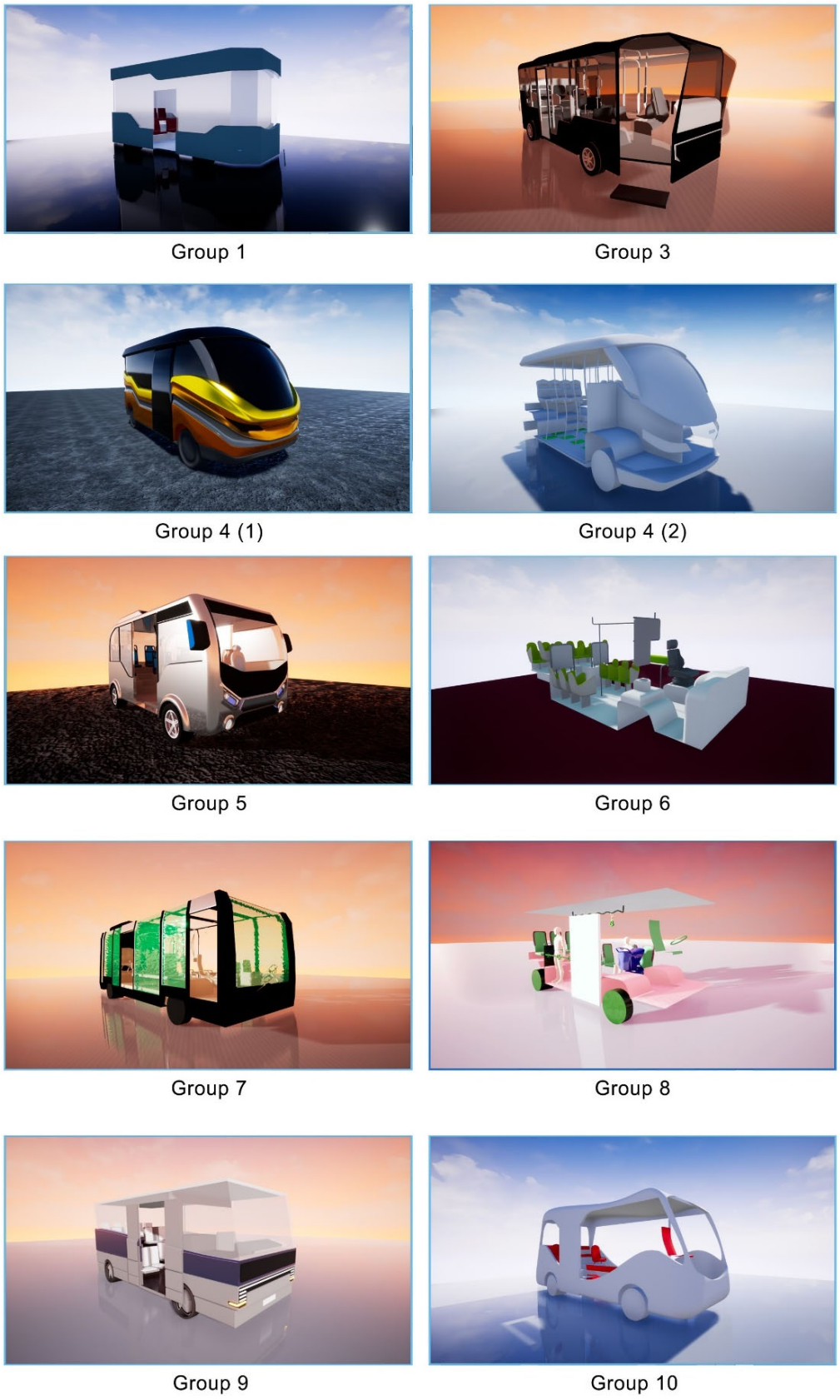


Figure 5.44 : Screenshots from the VR scenes submitted for the second preliminary jury.

Observation 5. It was observed that the VR scenes of some groups were not experienced by any jury members during their jury sessions. Hence, the jury durations of the project groups and the durations of experiencing their VR scenes by the jurors were calculated after the preliminary jury session. These durations are presented in Table 5.17. Apart from the jury members, among the guests who came to watch the jury session, those who wanted to experience the VR scenes were allowed to experience the VR scenes. Besides, the researcher, who took part as the operator in this jury session, also experienced some VR scenes for control, when he was not sure whether it was working correctly or not. For these reasons, the durations of experiencing their VR scenes by the operator and/or guests are also presented in this table.

Table 5.17 : Jury durations of the project groups and the durations of experiencing the VR scenes during the jury session.

Project Group	Jury Duration	Durations of experiencing the VR scenes					
		Juror 1	Juror 2	Juror 3	Juror 4	Juror 5	Operator and/or Guests
Group 1	1331 s (22 m 11 s)	102 s (BJ)	30 s (BJ)	38 s (BJ)	28 s (BJ)	20 s (BJ)	41 s (BJ)
Group 2	1947 s (32 m 27 s)	The VR scene of this group could not be run.					
Group 3	1729 s (28 m 49 s)	57 s + 88 s	–	–	59 s	75 s	45 s +56 s
Group 4	1228 s (20 m 28 s)	–	–	–	41 s + 93 s	–	36 s
Group 5	2005 s (33 m 25 s)	–	–	–	–	28 s	42 s + 44 s + 13 s + 3 s + 83 s
Group 6	1357 s (22 m 37 s)	–	–	–	–	–	–
Group 7	1389 s (23 m 9 s)	–	–	–	–	–	46 s
Group 8	1375 s (22 m 55 s)	–	–	–	–	–	18 s
Group 9	1011 s (16 m 51 s)	–	–	–	–	–	8 s + 37 s + 32 s + 66 s
Group 10	1200 s (20 m)	–	–	–	–	–	–

BJ: Before Jury (training purposes for the jurors), **m:** minute(s), **s:** second(s)

Since the VR scene of the first group was experienced by the jury members for training purposes, all jury members had to experience the VR scene of the first group. However, there was no other VR scene experienced by all jurors. Even, the VR scenes

of Groups 6,7,8,9, and 10 were not experienced by any jury members. Jurors 2 and 3 did not experience any of the VR scenes except for the first one that was used for training purposes.

Observation 6. It was observed that the jury members used the VR headset by holding it like binoculars with one hand rather than by wearing it properly. (Figure 5.45).

Figure 5.45 : Some photos that show how the jurors use the VR headset.

(b) Interviews

In the following days after the jury session, interviews were held with both the students and the jury members who were also the instructors of the course. The interviews with the students were held as group interviews, whereas the interviews with the instructor-jurors (Juror 1, 2, and 3) were held one-to-one. Since it was not possible to hold face-to-face interviews with the invited jury members (Juror 4 and 5), their opinions were tried to be gotten via e-mail. These first-round interviews were conducted to collect as much data as possible on the use of VR in jury sessions. Hence, these interviews were started with an unstructured format and went on with a semi-structured format.

Regarding the use of VR in the jury session, the topics below were covered in these interviews:

- whether the use of VR technology in this jury session was useful or not,
- the ease or difficulty of the use of it in this jury session,
- the positive and negative effects of the use of it in this jury session.

Additionally, to question whether students had difficulty in turning their CAD models into a VR scene, they were asked the questions below at the end of the interviews:

- What software did you use to create your CAD model?
- How long did it take to create your CAD model?
- How did you turn your CAD model into a VR scene? (by using the combination of export and import commands or the CAD integration feature of SimLab software?)
- How long did it take to turn your CAD model into a VR scene?
- What do you think about the difficulty or ease of creating a VR scene?

The analysis of these interviews was done qualitatively. In other words, this analysis focused on the contents of the statements, not the number of statements. Therefore, an analysis of how many times a statement was repeated by a participant or how many participants articulated that statement was not done.

Besides, when translating sentences into English, they were tried to be translated verbatim. In cases where it was not possible, they were tried to be translated in a way that their meaning would not change. All translations were done by the author.

The outcomes of these interviews are presented below.

Outcomes of the first-round interviews

As a result of the analysis of the transcription of the interviews' records, it was detected that;

1. One of the jury members had some prejudgments about using VR in the jury session, but these prejudgments were broken after the jury session (Table F.1 in Appendix F).

2. The fact that VR technology would be used in the jury session motivated the students to be well-prepared for the jury and increased their performances (Table F.2 in Appendix F).
3. The fact that the projects would be experienced in the VR environment caused some information missing in the design sheets of the students (Table F.3 in Appendix F).
4. The use of VR in the jury session made a significant contribution to the jurors' evaluation of the designs (Table F.4 in Appendix F).
5. The use of VR in the jury session positively affected the communication not only between the jurors and the designs but also between the jurors and students (Table F.5 in Appendix F).
6. The jurors needed to experience the VR scenes since there were missing or not been understood contents on the design sheets and/or there were some details not mentioned in the oral presentations (Table F.6 in Appendix F).
7. The jury members experienced only a few of the VR scenes, not all of them, with such thoughts as
   - experiencing each VR scene one by one extends the jury duration allocated to each project group and thus total jury duration,
   - experiencing the design in the VR environment when other jurors are commenting on that design via the design sheets causes a loss of focus on both the students and other jurors,
   - experiencing the projects in the VR environment causes the jury process to slow down.

   However, watching what someone sees on the screen while s/he was experiencing a VR scene made the jurors who did not experience that scene feel good and led them to believe that they did not miss critical points they had to see (Table F.7 in Appendix F).
8. When their VR scenes were not experienced by one juror or more than one jurors, students who put a lot of effort into creating their CAD model felt bad and/or thought that their effort was wasted and their projects were not fully understood by the jurors who did not experience their VR scene (Table F.8 in Appendix F).

9. The jury members used the VR headset by holding it like binoculars with one hand rather than by wearing it properly since they did not intend to spend much time in the VR environment (Table F.9 in Appendix F).
10. Although the jurors think that watching what someone sees on a screen while s/he is experiencing a VR scene was beneficial for them, they think that a video animation prepared in advance has not the equivalent effect (Table F.10 in Appendix F).
11. The VR headset was found easy to use. However, the way of its use in the proposed jury setup was considered as:

    — distracting,
    — time-consuming,
    — complicated,
    — troublesome,
    — unsystematic, and
    — ineffective (Table F.11 in Appendix F).

    The jurors desired

    — to use the VR glasses by sitting in their chairs,
    — to be able to experience the VR scenes simultaneously with the others and/or whenever they want,
    — to be able to contribute to the jury discussion by commenting and showing the things in the VR environment,
    — to be able to comfortably and clearly see what a person sees while s/he is experiencing a VR scene,
    — not to disrupt the jury process while using VR, and
    — the areas reserved for the VR experience and presentations to be separate from each other to be able to experience the VR scenes in comfort and safe (Table F.11 in Appendix F).

    The students desired

    — to be able to comfortably and clearly see what a juror sees while s/he is experiencing a VR scene,

— not to be distracted by the VR use of the jurors or others while presenting their design proposals, and

— to be able to show and explain the things in their VR scenes (Table F.11 in Appendix F).

12. Students had no difficulty in turning their CAD models into a VR scene although they used different CAD software to create them and different methods to transfer them to the VR scene (Table 5.18).

Table 5.18 : Students' responses to the questions regarding the process of creating their CAD models and turning them into a VR scene.

Project Group	CAD software used by the group	Perceived duration of CAD model creation	Methods used for transferring the CAD model into the VR scene	Perceived duration of creating/pre-paring a VR scene with that CAD model	Perceived easiness/difficulty level of VR scene preparation
Group 1	SolidWorks	10 hours	Export + Import	10 minutes	Very easy
Group 2	Rhinoceros + Fusion 360	32-34 hours	Export + Import	15 minutes	Easy
Group 3	SolidWorks	10 hours	Export + Import	20-30 minutes	Easy
Group 4	SolidWorks + 3ds Max	12-13 hours	Export + Import	5-10 minutes	Very easy
Group 5	SolidWorks	13 hours	Export + Import	5-10 minutes	Very easy
Group 6	SolidWorks	10 hours	Export + Import	10 minutes	Very easy
Group 7	Rhinoceros + Maya	5-6 hours	Export + Import	5-10 minutes	Very easy
Group 8	Rhinoceros	15 hours	CAD Integration	15 minutes	Easy
Group 9	Rhinoceros	8-9 hours	CAD Integration	15-20 minutes	Easy
Group 10	SolidWorks	6-7 hours	Export + Import	10-20 minutes	Easy

Reflect: reflecting on the findings of the 1st cycle of mandatory use

1. Using VR in the jury session did not cause a lot of extra workload and difficulty for the students.

2. Using VR in the jury session as a supporting design evaluation tool was accepted by the jurors whereas using it as a design representation tool was over-accepted by the students.

   This first attempt to integrate VR into the jury practice had been planned with the thought that VR would be used by students as a supporting design representation tool and as a supporting design evaluation tool by the jurors. However, students treated VR as the main design representation tool. They omitted some of the

information that was expected to be in their design sheets and did not make any physical model or mock-up. On the other hand, jurors acted as expected by believing that VR would support them in evaluating the designs and tended to use VR when they needed it.

3. The proposed way to use VR in this jury session was not accepted by both the jury members and the students.

   The proposed way of VR use made the juror think "If I experience this VR scene, the flow of the jury process will slow down, the jury duration will extend, and the students and other jurors will be distracted". For this reason, in most parts of the jury session, jurors avoided using VR even though they wanted to use it. On the other hand, the students whose VR scenes were not experienced by any of the jurors complained that their VR scenes were not experienced, whereas the students whose VR scenes experienced complained about using VR in this way since it causes distraction and consuming time. Besides, almost all jurors and students complained about not being seen comfortably and clearly what someone sees while s/he is experiencing a VR scene.

4. It was revealed that the way of VR use in jury sessions should first be not time-consuming, disrupting, and distracting, then be enabled all jurors and students to see what someone sees while s/he is experiencing a VR scene.

5.2.5.2 The 3rd preliminary jury session: the 2nd cycle of mandatory use

Plan: planning the 3rd preliminary jury session

In the first attempt, using VR in the jury session was accepted, but its way of use was not accepted. Therefore, for the second attempt to integrate VR into the jury practice, both the way of its use and the jury setup layout previously proposed were revised by only focusing on improving the way of its use. Figure 5.46 shows the revised version of the jury setup layout. The changes made are presented below with the reasons behind them.

1. It was observed, in the previous jury session, that

   — the jury members were reluctant to get up from their chairs each time to experience the VR scenes (Observation 4 in the first cycle), and

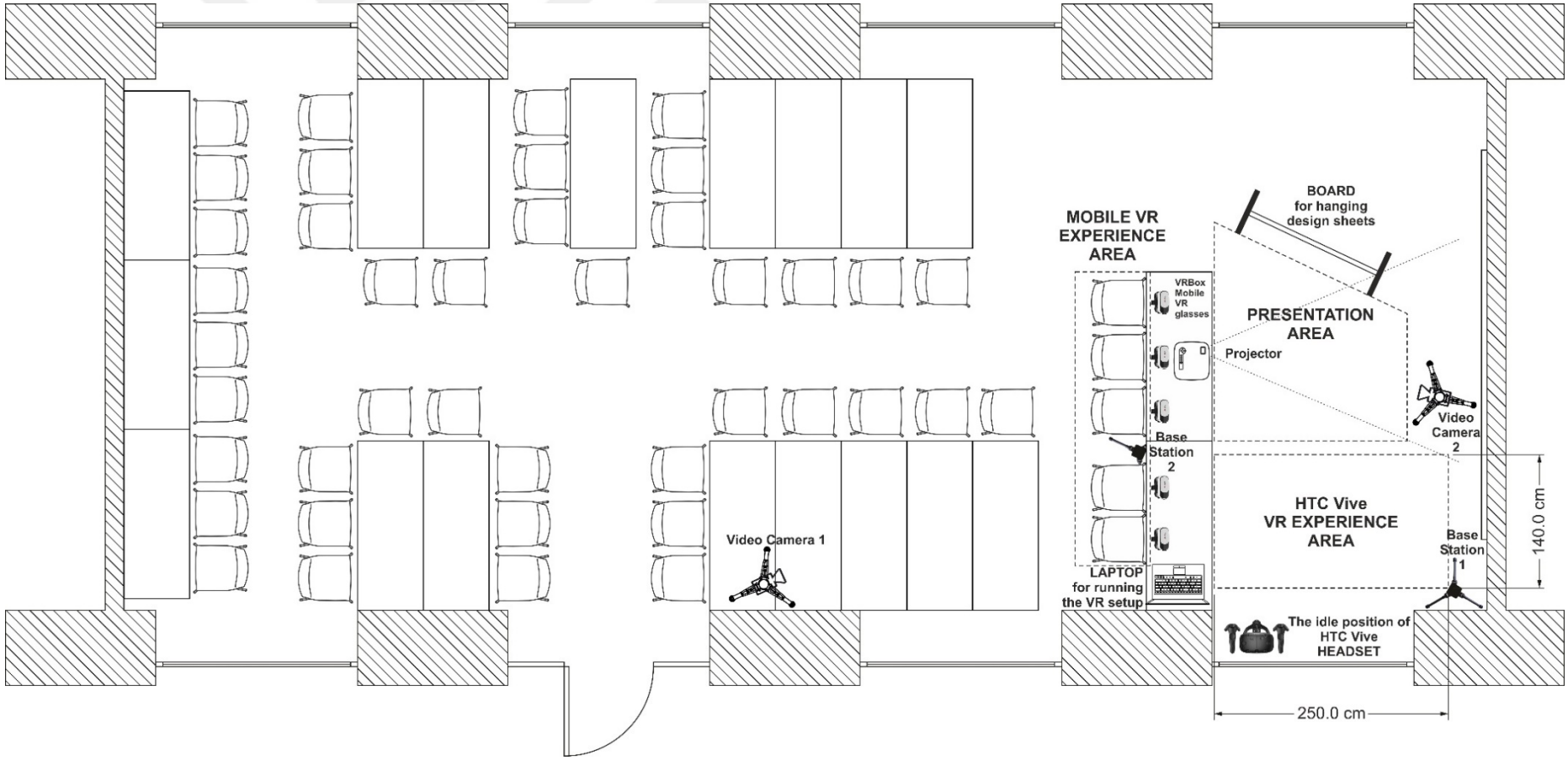


Figure 5.46 : Proposed jury setup layout for the 3rd preliminary jury session.

— when they used the VR headset, by holding it like binoculars with one hand rather than by wearing it properly, they tried to use it in a way that would not take too much time (Table 5.17 and Observation 6 in the first cycle).

Also, by the jurors, it was demanded

— being able to use VR without standing up not to distract others or disrupt the jury flow (Table F.11 in Appendix F), and

— being able to experience VR scenes whenever and as long as they want (Table F.11 in Appendix F).

For these reasons, mobile VR glasses presented in Figure 5.47 were provided for each jury member. Thus, jurors would be able to experience VR scenes by placing their smartphones in these mobile VR glasses. In this way, they would be able to experience VR scenes more practically, whenever and as long as they want without leaving their chairs, distracting others, and disrupting the jury flow.

Figure 5.47 : VR Box mobile VR glasses, taken from (URL-10).

Since using mobile VR glasses in the jury session was planned, the SimLab VR viewer application had to be installed on the jury members' smartphones so that they could use these mobile glasses with their own smartphones. For this reason, the download link of the installer file of this app was shared with them, and they were asked to install it on their smartphones before coming to the jury session. On the other hand, students had to submit their VR scenes in a compatible format with

the SimLab VR Viewer. However, they did not know how to convert their VR scenes to this kind of format. Hence, they were asked to come to the studio with their VR scenes one hour before the 3rd preliminary jury session so that the researcher could teach them how to do it by demonstrating.

2. The jurors desired to be able to contribute to the jury discussion by commenting on and showing the things in the VR environment, whereas the students desired to be able to show and explain the things in their VR scenes (Table F.11 in Appendix F). They also demanded being able to comfortably and clearly see what a juror or another person sees while s/he is experiencing a VR scene (Table F.11 in Appendix F). However, meeting these demands was not possible by using only mobile VR glasses since the VR screens of these devices could not be projected on a screen or wall. For this reason, the HTC Vive VR setup was included as well in the revised version of the jury setup layout, but this time, the HTC Vive headset was accompanied by a projector projecting its VR screen onto the wall. In this way, jurors would be able to comment in the VR environment by showing what they were commenting on, and students would be able to present the design details in the VR scene by showing them if they wanted.
3. Another demand was to be set the areas allocated to VR experience and presentations separately from each other to experience VR scenes comfortably and safely (Table F.11 in Appendix F). Hence, the areas reserved for VR experience and presentations were set separately from each other.

On the other hand, the anticipation regarding the tentative stages of the jury session where VR would be employed was revised as follows:

1. Students will explain their design details and decisions behind them by referring to the representations of the designed product, such as its drawings and renderings on their design sheets, and its physical model(s).
2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information, if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets and/or (a) physical model(s),

— jurors can experience the designs individually by using the VR Box mobile VR glasses or the HTC Vive VR headset for better understanding and evaluation. If they prefer to use the HTC Vive VR headset, they also can contribute to the jury discussion by commenting on and showing the things in the VR environment,

— students, if they wish, can explain the issues that are misunderstood or not understood by showing the things in their VR scenes with the help of the HTC Vive VR headset.

Act: performing the 3rd preliminary jury session by using VR

The 3rd preliminary jury was performed on May 4, 2018.

As mentioned before, students came to the studio with their VR scenes one hour before the jury session. The researcher taught them how to convert their VR scenes to a compatible format with the SimLab VR Viewer by demonstrating. They converted their VR scenes by following the steps in the demonstration, and then, they submitted them.

The seating plan of Studio 217B was changed as in Figure 5.46 before the jury session. However, Juror 3 could not attend this jury session due to having to attend another meeting at that time, and none of the other jurors did not prefer to sit on the chairs between Base Station 2 and the wall. For this reason, the seating plan was rearranged as shown in Figure 5.48 and Figure 5.49. In these figures, the positions of two video cameras used for recording the jury session are also shown. This jury session, as well, was recorded with two video cameras and a voice recorder.

Also, for this jury session, it was planned to use mobile VR glasses with jurors' smartphones. However, the SimLab VR Viewer app could not be run properly on the smartphones of Juror 1, 2, and 3. Juror 3 already could not attend this jury session. Juror 5 did not want to use his own smartphone as a personal preference in this preliminary jury session. For these reasons, the researcher gave his smartphone to jurors to be used with mobile VR glasses. As a result, in this preliminary session, only two mobile VR glasses could be used with the smartphones belonging to Juror 5 and the researcher. The information regarding the brands and models of the smartphones of jury members and the researcher was presented in Figure 5.50.

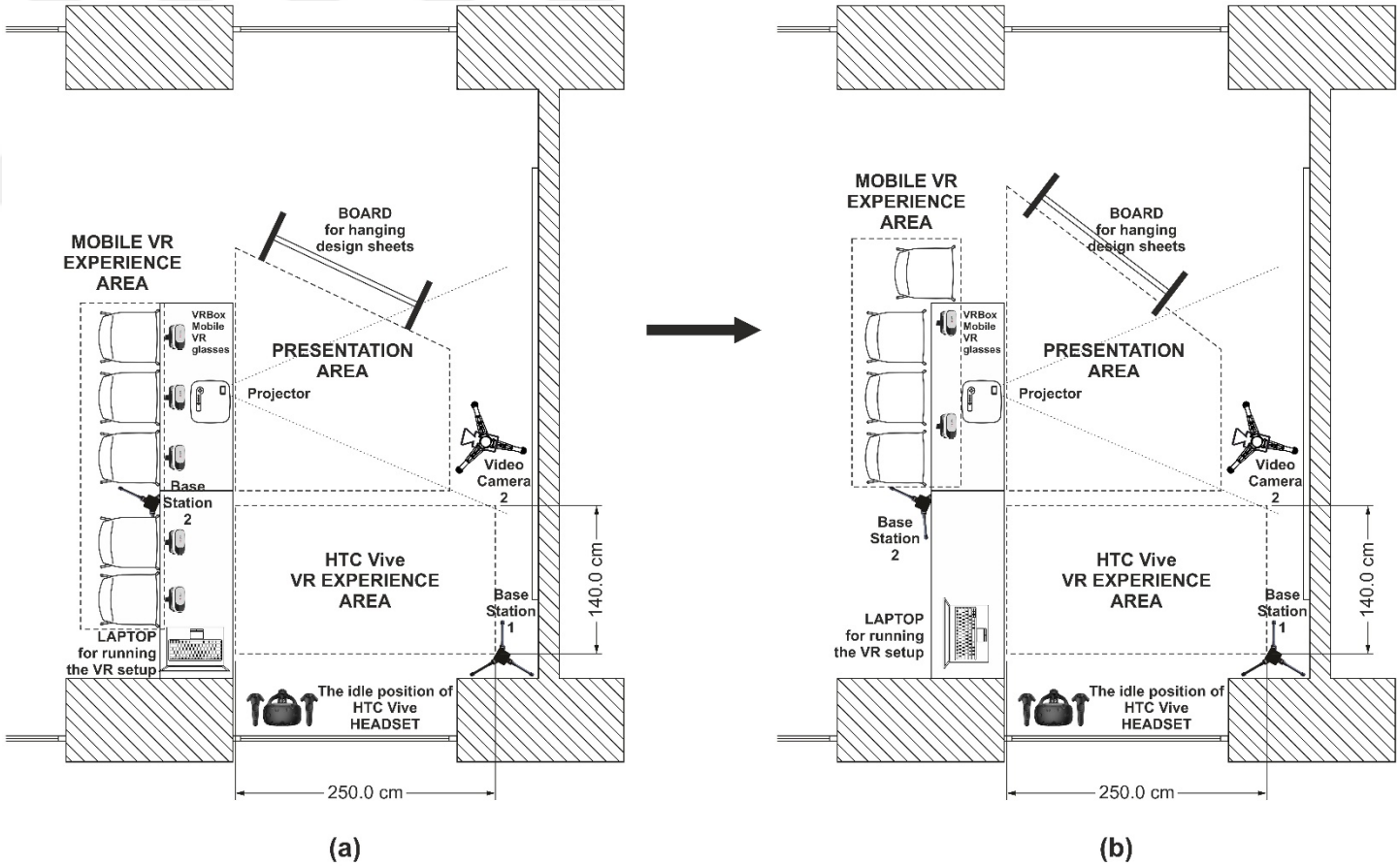


Figure 5.48 : Changes made in the jury setup layout immediately before the jury session: (a) is the proposed layout and (b) is the changed version of the layout.

Figure 5.49 : Photos showing the jury setup in the 3rd preliminary jury session and the way of using VR by the jurors within it.

Figure 5.50 : Smartphones of jury members and the researcher.

At the beginning of the jury session, it was announced

— to jurors that they could experience the design individually by using the VR Box mobile VR glasses or the HTC Vive VR headset, and if they prefer to use the HTC Vive VR headset, they also could show what they saw in the VR environment to others.

— to students that if they wish, they could use the HTC Vive VR headset during their jury sessions for any purpose such as presenting the design proposal and/or explaining the issues that are misunderstood or not understood by showing the things in their VR scenes.

Before the first presentation, the researcher wanted to give brief training to jurors regarding how to use the SimLab VR Viewer to experience VR scenes. However, downloading the VR scenes on the smartphones took too much time. When the download ended, the jurors did not want to waste any more time and wanted the jury session to begin as soon as possible. Hence, they learned by trial and error how to use mobile VR glasses to experience the VR scenes during the first few presentations.

In this jury session, the researcher again took place as an operator who is only responsible for installing and running the VR systems properly, and also responsible for its being used easily.

This preliminary jury session lasted approximately 3 hours except for the break times. Each group's jury session lasted an average of 17 minutes. The exact times are presented in the following section.

Observe: questioning what happened in the 3rd preliminary jury session

(a) Observations

Observation 1. Throughout this preliminary jury session, there was no request for changes regarding the proposed jury setup layout.

Observation 2. Although it was announced to students that they were free to benefit from any kind of design representation for presenting their design ideas, none of the project groups made, submitted, and presented any physical mock-ups and/or models for/in this preliminary jury as well.

Observation 3. The VR scenes (Figure 5.51) of the groups had not included user-product interactions such as opening and closing the doors of the vehicle and turning

on a light by pressing a button, but they included the basic VR interactions such as walking, jumping, and moving the head for the 360-degree experience of the virtual model.

Figure 5.51 : Screenshots from the VR scenes submitted for the third preliminary jury.

Observation 4. The VR scenes of the groups were experienced by at least one juror in this preliminary jury session (Table 5.19).

Table 5.19 : Jury durations of the project groups and the durations of experiencing the VR scenes during the jury session in the 3rd preliminary jury.

Project Group	Jury Duration	Duration of experiencing the VR scene with the mobile VR glasses				
		Juror 1	Juror 2	Juror 3	Juror 4	Juror 5
Group 1	920 s (15 m 20 s)	36 s	—	Not attended the jury session	—	31 s
Group 2	881 s (14 m 41 s)	20 s	10 s + 50 s + 11 s + 9 s		33 s + 5 s + 8 s + 5 s + 2 s	18 s
Group 3	1247 s (20 m 47 s)	61 s + 36 s	—		14 s + 46 s + 23 s + 3 s	25 s + 24 s + 32 s + 42 s + 6s
Group 4	974 s (16 m 14 s)	58 s	—		152 s + 14 s + 3 s + 6 s +6 s + 15 s	130 s
Group 5	1340 s (22 m 20 s)	34 s + 4 s + 9 s + 26 s	—		18 s + 22 s + 41 s	24 s
Group 6	827 s (13 m 47 s)	30 s	—		36 s + 37 s + 22 s	32 s + 5 s
Group 7	1457 s (24 m 17 s)	35 s	97 s		37 s + 18 s	87 s + 15 s
Group 8	1300 s (21 m 40 s)	5 s + 24 s	10 s + 125 s		17 s + 9 s + 7 s	13 s
Group 9	639 s (10 m 39 s)	—	112 s		—	—
Group 10	907 s (15 m 7 s)	—*	—		82 s	47 s + 6 s

m: minute(s), **s:** second(s), *:The juror did not attend this session.

Observation 5. Except for Group 7, none of the groups preferred to use the combination of the HTC Vive headset and the projector to present their design proposals and/or explain the issues that are misunderstood or not understood by showing the things in their VR scenes. One of the students of Group 7 wore the HTC Vive VR headset at the end of their presentation and told once again their design proposals by showing the things in their VR scene and then answered the jurors' questions by pointing out the related parts in their virtual model. This part in the jury session of Group 7 lasted 4 minutes and 35 seconds. During this presentation, the jurors sometimes directed verbally the student in the VR environment to show the things that they wanted to see again or ask a question about.

Observation 6. None of the jurors preferred to use the combination of the HTC Vive headset and the projector. They preferred to give verbal feedback on the critical issues that they detected in the VR environment by pointing at the design sheets or directly

showing them by going in front of the board that the design sheets hung on (Figure 5.52).

Figure 5.52 : Two photos showing how jurors gave feedback on the critical issues that they detected in the VR environment.

Observation 7. With the help of mobile VR glasses, the jurors were able to experience VR scenes practically, whenever and as long as they want without leaving their chairs. They were even able to take a glance at VR scenes very quickly while presentations or jury discussions were in progress.

Figure 5.53 : Some photos showing how the jurors use mobile VR glasses.

Observation 8. Jury members had to rotate their upper bodies to their left or right – even to their back – while they were sitting in their chairs in order to be able to navigate

within the VR scenes. Because of this, one of the jurors sometimes had difficulty in experiencing the VR scenes, and she preferred to experience them by standing up (Figure 5.53).

(b) Interviews

In the following days after the jury session, interviews were again held with both the students and the jury members who were also the instructors of the course. And again, the interviews with the students were held as group interviews (one of the students was excluded due to not attending the interview session), whereas the interviews with the instructor-jurors (Juror 1 and 2) were held one-to-one. Since it was not possible to hold face-to-face interviews with the invited jury members (Juror 4 and 5), their opinions were tried to be gotten via e-mail. Juror 3 was excluded due not to attend this jury session.

As mentioned before, in the first attempt, to use of VR in the jury session was accepted, but its way of use was not accepted. Hence, the second attempt was planned by only focusing on improving the way of VR use. In other words, this planning aimed to eliminate the complaints of jurors and students about the previous way of use for VR, such as its being time-consuming and causing distractions and disruptions. Therefore, in these second-round interviews, whether this planning achieved its purpose was discussed by asking the questions presented in Table 5.20 to jurors and students.

Outcomes of the second-round interviews

As a result of the analysis of the transcription of the interviews' records, it was detected that;

1. The proposed way of VR use in the second cycle was evaluated as a better way than the previous one (Table F.12 in Appendix F).
2. Although Juror 1 and 4 did not experience 2 VR scenes and Juror 5 did not experience 1 VR scene, they did not remember that they did not experience them. Juror 2 did not experience 6 VR scenes. However, s/he did not attribute the reason behind this situation to the way of VR use in the jury session. S/he reported that she was unable to experience them since she was busy with other works during that time (Table F.13 in Appendix F).

Table 5.20 : Questions asked to jurors and students in the second-round interviews.

	Questions asked to jurors		Questions asked to students
1	Would you evaluate the way of VR use in this jury session comparatively with the way of VR use in the previous jury session?	**1**	Would you evaluate the way of VR use in this jury session comparatively with the way of VR use in the previous jury session?
2	Did you experience the VR scenes of all groups in this jury session? If no, why?	**2**	Did all jurors experience your VR scene in this jury session? If no, what did you think and feel when your VR scene was not experienced by one juror or more than one juror?
3	While you were experiencing a VR scene by using the mobile VR glasses during the jury session, a. Were you distracted? b. Did you ever think that you lost contact with the ongoing presentation or jury discussion, and/or your communication and interaction with it was disrupted? And, while a jury member next to you was experiencing a VR scene by using the mobile VR glasses during the jury session, a. Did you ever think that s/he was distracted? b. Did you ever think that s/he lost contact with the ongoing presentation or jury discussion, and/or her/his communication and interaction with it was disrupted? c. Did you ever think that s/he distracted you and/or disrupted your communication and interaction with the ongoing presentation or jury discussion? d. Did you ever think that s/he distracted other jurors and/or disrupted their communication and interaction with the ongoing presentation or jury discussion? e. Did you ever wonder what s/he saw and/or where s/he looked in the VR scene?	**3**	While a jury member in front of you was experiencing your VR scene by using the mobile VR glasses in your jury session, a. Did you ever think that s/he was distracted? b. Did you ever think that s/he lost contact with the ongoing presentation or jury discussion, and/or her/his communication and interaction with it was disrupted? c. Did you ever think that s/he distracted you and/or disrupted your communication and interaction with the ongoing presentation or jury discussion? d. Did you ever think that s/he distracted other jurors and/or disrupted their communication and interaction with the ongoing presentation or jury discussion? e. Did you ever wonder what s/he saw and/or where s/he looked in your VR scene?

Table 5.20 (continued) : Questions asked to jurors and students in the second-round interviews.

	Questions asked to jurors		Questions asked to students
4	What do you think about whether the way of VR use in this jury session is time-consuming and/or troublesome?	**4**	What do you think about whether the way of VR use in this jury session is time-consuming and/or troublesome?
5	In this jury, one of the groups used the HTC Vive VR setup whose VR screen was projecting onto the wall to present their design and to answer the jurors' questions by pointing out the related parts in their virtual model. What do you think about using VR by students in this way?	**5**	In this jury, one of the groups used the HTC Vive VR setup whose VR screen was projecting onto the wall to present their design and to answer the jurors' questions by pointing out the related parts in their virtual model. What do you think about using VR in this way?
6	Although the HTC Vive VR setup was also present for your use, you never used it during the jury session. You preferred to use the mobile VR glasses only. Why?		
7	Mobile VR equipment was provided to each juror. However, only two of them were able to be used. Did this situation cause any trouble?		
8	Why did you need to experience the VR scenes?		
9	How VR should be employed in the next jury session?	**6**	How VR should be employed in the next jury session?

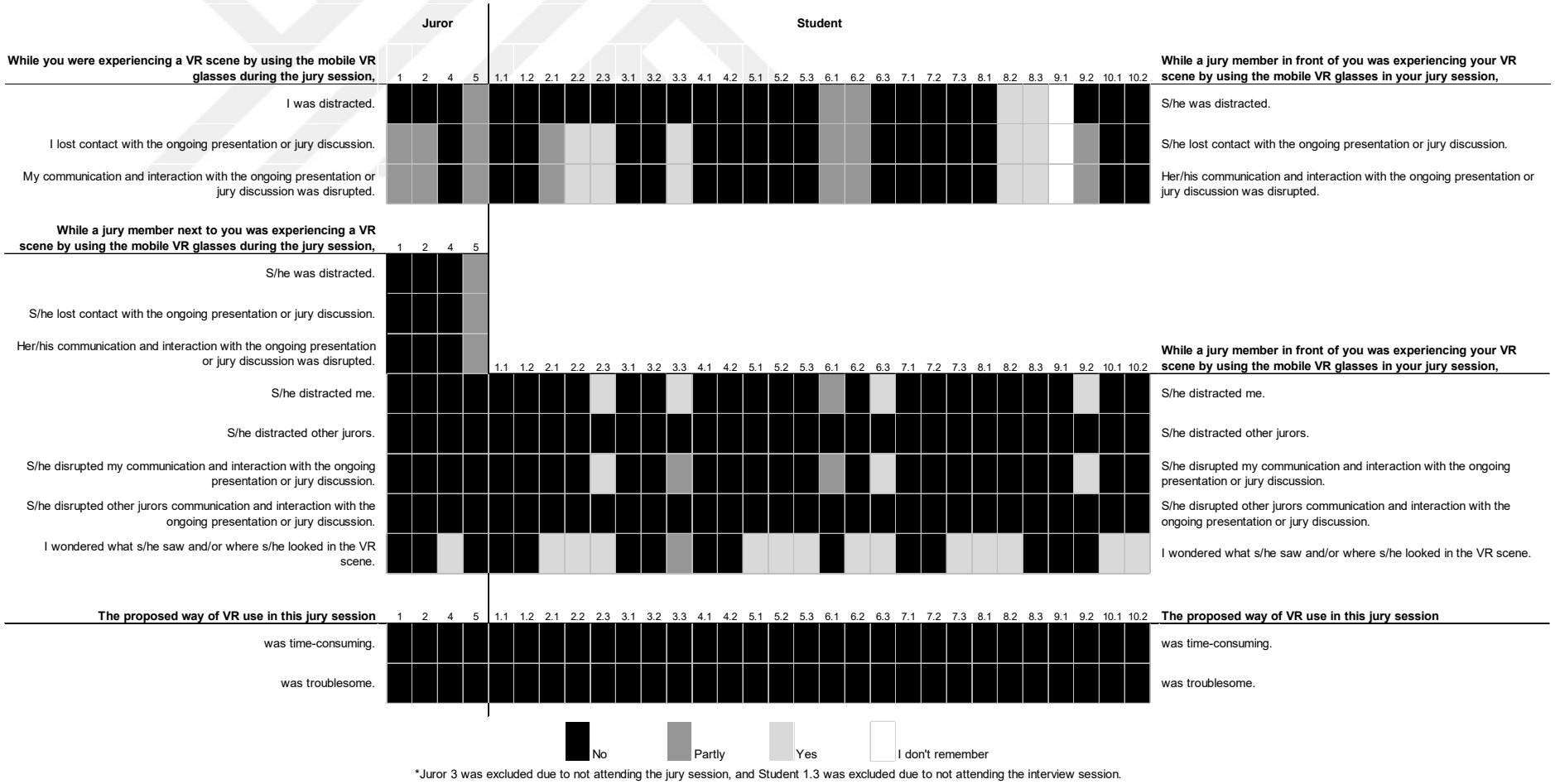
On the other hand, most of the students were not able to clearly remember whether all jurors experienced their VR scene. Some of them reported that giving a presentation in front of the jury was very exciting for them. For this reason, they did not pay attention or could not monitor who experienced their VR scene and who did not. Accordingly, the students whose VR scenes were not experienced by one or more jurors did not report any negative feelings or thoughts regarding this situation (Table F.14 in Appendix F).

3. Juror 1, 2 and 5 reported that they partly lost contact with the ongoing presentation or jury discussion and their interactions were partly disrupted while experiencing the VR scenes. However, Juror 1 and 2 declared that these circumstances did not cause to distract them and disturb their concentrations on the ongoing presentation or jury discussion. Juror 5 stated that s/he was distracted partly. Juror 4 reported that neither s/he was distracted, nor s/he lost contact with the ongoing presentation or jury discussion, nor her/his interaction with it was disrupted while experiencing the VR scenes (Figure 5.54).

   On the other hand, more than half of the students and jurors reported that while a juror in front of or next to them was experiencing a VR scene, they felt that neither s/he was distracted, nor s/he lost her contact with the ongoing presentation or jury discussion, nor her/his communication and interaction with it was disrupted (Figure 5.54).

   Moreover, most of the students and all jurors stated that while a juror in front of or next to them was experiencing a VR scene, s/he neither distracted them, nor disrupted their communication and interaction with the ongoing presentation or jury discussion. Besides, none of the students and jurors thought that while a juror was experiencing a VR scene, s/he distracted other jurors and/or disrupted their communications and interactions with the ongoing presentation or jury discussion (Figure 5.54).

   Regarding the fact that the VR screen of the mobile VR glasses could not be projected onto a wall or a screen, one juror and half of the students articulated that, while a jury member was experiencing a VR scene by using the mobile VR glasses, they wondered what s/he saw and/or where s/he looked in the VR scene. When analyzed their full answers to the question, it was seen that;



*Juror 3 was excluded due to not attending the jury session, and Student 1.3 was excluded due to not attending the interview session.

Figure 5.54 : Responses to the question 3 and 4 in Table 5.20.

— The juror wondered what was in the VR scene, not what a juror experiencing that VR scene saw and/or where s/he looked in that VR scene,

— Some of the students did not wonder about it in their jury sessions but wondered about it while watching other jury sessions. Because there was no image from the VR scenes of the groups in the jury setup. So, these students as well wondered what was in the VR scene rather than what the juror experiencing it scene saw and/or where s/he looked in it, and

— Other students did not wonder about it in the cases the juror gave feedback about it verbally but wondered about it in the cases s/he did not give any feedback verbally.

4. The proposed way of VR use in this preliminary jury session was found as not time-consuming and troublesome (Figure 5.54).
5. The way of VR use in the jury session of Group 7 was qualified by the words "good, better, very effective, more useful, explanatory, advantageous, logical, and interesting" and appreciated by most of the students and jurors (Table F.15 in Appendix F).
6. Jurors did not prefer to use the HTC Vive setup with such thoughts as

   — experiencing the VR scenes by using the HTC Vive setup disrupts the jury process,

   — experiencing the VR scenes by using the HTC Vive setup extends the jury duration allocated to each project group and thus total jury duration,

   — the mobile VR glasses are handier, more practical, and more suitable for their needs than the HTC Vive setup (Table F.16 in Appendix F).

   J2 also stated that due to the placement of the HTC Vive setup, s/he also thought it was set up for students to use (Table F.16 in Appendix F).
7. Although only two of five mobile VR equipment provided for jurors to use were able to be used in the jury session, this situation was not considered as a situation causing trouble by most of the jurors. Only one jury member stated

that s/he was discomforted by the shared use of equipment that touches their skins[13] (Table F.17 in Appendix F).

8. Different from the previous jury session, the reason behind that the jurors needed to experience the VR scenes was mainly based on that the students could not explain some design details verbally via their design sheets (Table F.18 in Appendix F).
9. For the next jury session, it was stated that students should present their designs by using the HTC Vive setup as Group 7 did. In addition, the sheets in A3 size were found too small, and it was requested to display them in large size. Apart from these expectations, one of the jury members articulated that it will be good if there are revolving (swivel) chairs for the jurors (Table F.19 in Appendix F).

Reflect: reflecting on the findings of the 2nd cycle of mandatory use

1. To use mobile VR glasses for experiencing the VR scenes by the jurors in the jury session was accepted.
2. The use of the HTC Vive setup for presentation purposes by students rather than the use of it by jurors for evaluation purposes would be more suitable in terms of the integration of VR into the jury practice. On the other hand, active use of the HTC Vive headset with a projector projecting its VR screen onto a wall or screen in all presentation sessions would also solve the problems regarding the lack of the images of VR scenes in the jury setup mentioned in the previous section.
3. Although the deficiencies in the design sheets of the students decreased, the need for VR use of the jurors did not decrease.
4. Students again did not need to use any physical mock-ups and/or models to show and/or explain their design decisions.
5. The fact that only two of five mobile VR equipment provided for jurors were able to be used in the jury session – in other words, the shared use of the mobile VR glasses – was not considered as a condition posing a critical problem that

[13] This study was conducted before the COVID-19 pandemic.

has to be solved for the next jury session[14]. Similarly, the fact that jurors had to rotate their upper bodies to their left or right – even to their back – while they were sitting in their chairs in order to be able to navigate within the VR scenes was also not considered as a critical problem.

6. The demands that were not directly related to the use of VR in the jury practice began to emerge, such as demanding the sheets to be displayed in large size.

5.2.5.3 The final jury session: the 3rd cycle of mandatory use

Plan: planning the final jury session

In the second attempt to integrate VR into the jury practice, using mobile VR equipment solved most of the problems identified in the first attempt regarding the way of VR use by the jurors. For this reason, it was decided to keep using this equipment by the jurors in the same way.

Besides, in the second attempt, it was noticed that the use of the HTC Vive setup for presentation purposes by students would be more suitable in terms of the integration of VR into the jury practice. Hence, it was decided to keep it as well in the jury setup, but only for presentation purposes, and it was announced to students that they were expected to use the HTC Vive VR setup in their presentations, and they could practice giving a presentation with VR till the end of the lessons.

On the other hand, it had been demanded the sheets to be displayed in large size for this jury session. Besides, as mentioned before in the section "5.2.3 Brief of the selected project", students had to submit a 1/10 scale physical look-like model for the final jury. Therefore, the jury setup was revised as in Figure 5.55 by adding

- one more projector, laptop, and board for presenting the digital format of the sheets by displaying them in large size, and
- two more tables: one for placing the laptops and the tabletop projector on, and one for the physical model presentations of students.

Apart from these, since students would be one more time asked to submit their VR scenes in a compatible format with mobile devices, a manual showing how to convert

[14] This study was conducted before the COVID-19 pandemic.

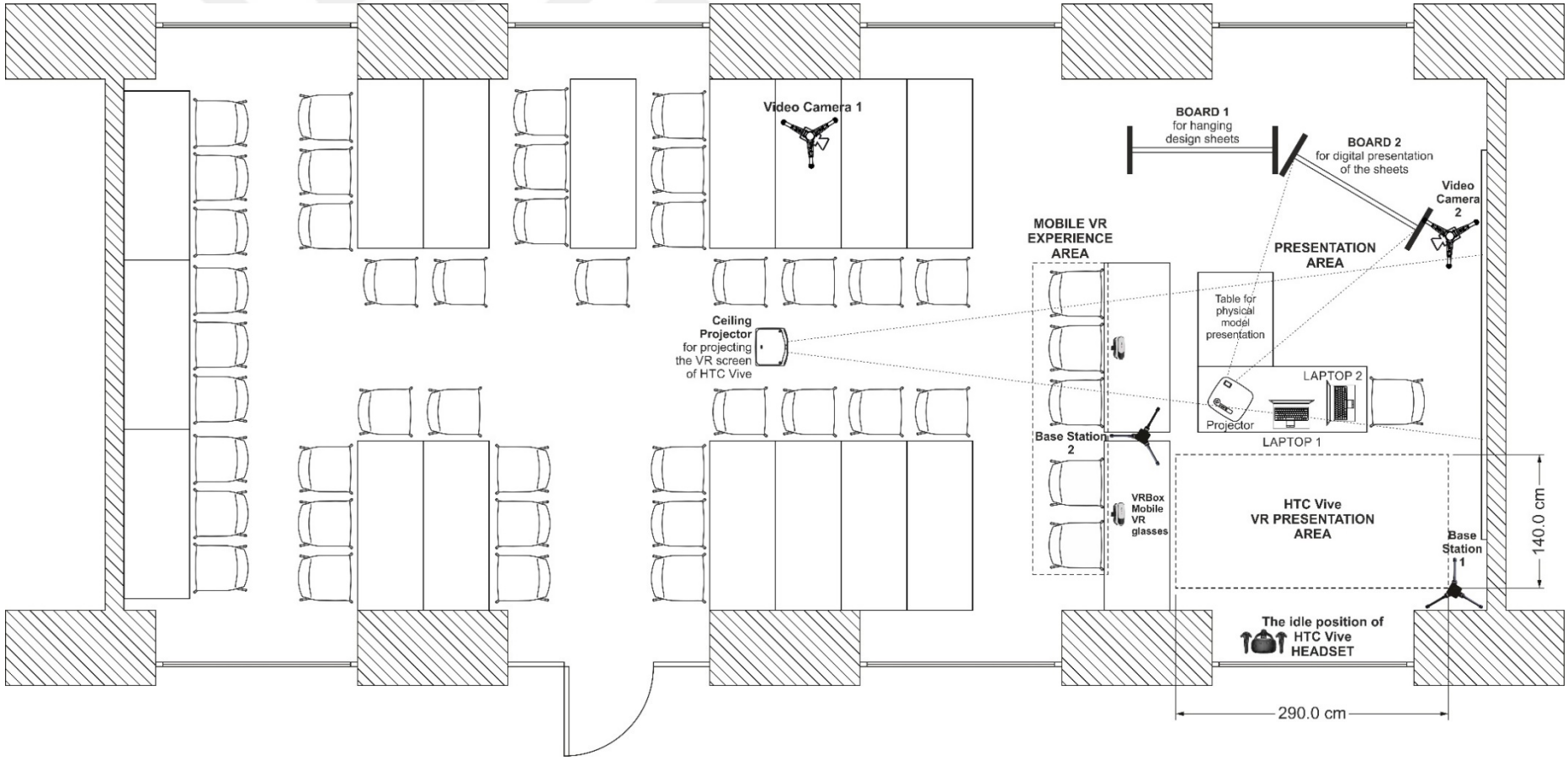


Figure 5.55 : Proposed jury setup layout for the final jury session.

a VR scene into a format that is compatible with mobile devices by using SimLab Composer 8.0 was handed out to them. This manual prepared by the researcher for facilitating this duty of the students is presented in Appendix C.

The second attempt, as mentioned above, revealed the potential of using the HTC Vive setup by students for presentation purposes in terms of integrating VR into the jury practice of industrial design education. However, the students thought that it could be used in two ways in the final jury session (Table F.19 in Appendix F):

- *Option 1:* One of the group members wears the HTC Vive VR headset and enters into their VR scene, and then gives an oral presentation by showing the design details/decisions over their virtual model in the VR scene, or
- *Option 2:* One of the group members wears the HTC Vive VR headset and enters into their VR scene, and then shows what is being mentioned/told about at that moment while other members are giving the presentation.

In line with these thoughts, the anticipation regarding the tentative stages of the jury session where VR would be employed was revised as follows.

1. Students will explain their design details and decisions behind them not only by referring to the representations of the designed product, such as its drawings and renderings on their digital and non-digital design sheets, and its physical model(s), but also by using VR (HTC Vive setup) in one of the ways mentioned above (Option 1 or Option 2).
2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information, if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets, (a) physical model(s), and/or the virtual model in the VR scene
   - jurors can experience the design individually by using the VR Box mobile VR glasses for better understanding and evaluation,
   - students, if they wish, can explain the issues that are misunderstood or not understood by showing the things in their VR scenes with the help of the HTC Vive setup.

Act: performing the final jury session by using VR

The final jury was performed on June 1, 2018.

The seating plan of Studio 217B was changed as in Figure 5.55 before the jury session. However, a compatibility problem occurred between the HTC Vive setup and the ceiling projector. Hence, the HTC Vive setup was run with the tabletop projector. So, during the final jury session, students used the tabletop projector with Laptop 1 for their VR presentations, and the ceiling projector with Laptop 2 for their digital sheet presentations (Figure 5.56).

At the beginning of the jury session, it was reminded

— to jurors that they could experience the designs individually by using two VR Box mobile VR glasses, and

— to students that they were expected to use the HTC Vive VR setup for presentation purposes in their jury sessions.

In this jury session as well, the researcher again took place as an operator who is only responsible for installing and running the VR systems properly, and also responsible for its being used easily.

This preliminary jury session lasted approximately 3.5 hours except for break times. Each group's jury session lasted an average of 21 minutes. The exact times are presented in the following section.

Observe: questioning what happened in the final jury session

(a) Observations

Observation 1. Throughout the final jury session, there was no request for changes regarding the jury setup.

Observation 2. Each group made, submitted, and presented a 1/10 scale physical model. In addition to the 1/10 scale physical models of their design, four groups (Group 2, Group 3, Group 8, and Group 9) submitted and presented the 1/1 scale physical mock-ups of some parts of their designs:

— Group 2: the 1/1 scale mock-up of the cushion of the passenger seat,

— Group 3: the 1/1 scale mock-up of the dashboard of the vehicle with the steering wheel,

Figure 5.56 : Photos showing the jury setup in the final jury session, and the way of using VR, design sheets (digital and non-digital), and physical models within it.

— Group 8: the 1/1 scale mock-up of the grab handle,

— Group 9: the 1/1 scale mock-up of the passenger seating unit of the vehicle.

Observation 3. The VR scenes (Figure 5.57) of the groups had not included user-product interactions such as opening and closing the doors of the vehicle and turning on a light by pressing a button but they included the basic VR interactions such as walking, jumping, and moving the head for the 360-degree experience of the virtual model.

Observation 4. The VR scenes of the groups except for Group 3 were experienced by at least two jurors in this jury session (Table 5.21). The VR scene of Group 3 could not be run on the smartphones due to its big file size (233 megabytes) although it could be run with the HTC Vive setup.

Observation 5. The ratio of the duration of VR uses in the jury sessions of the groups to the total jury duration of the groups increased remarkably (Figure 5.58).

Observation 6. Group 3 and 8 selected Option 1 as the way of using VR in their presentations: the group member entering into the VR environment only showed what was being mentioned/told about at that moment during the presentation. However, other groups combined these two options except for Group 9: the group member entering into the VR environment gave an oral presentation by showing the design details/decisions over their virtual model in the VR scene and showed what was being mentioned/told about at that moment the rest of the presentation. Group 9 did not use the HTC Vive setup. Instead, they used the desktop VR mode of SimLab Composer 8.0 that allows viewing a VR scene on the computer screen without the need for any connection with a VR headset.

Observation 7. In the presentations of those groups that combined Option 1 and 2 as the way of using VR, during the use of VR as in Option 2, some little synchronization problems occurred between the group member giving the oral presentation and the group member showing what was being told about at that moment.

Observation 8. During the presentation of Group 4, the group member in the VR environment, while showing what was being told about at that moment, tapped accidentally on the arm of his group mate who was giving the oral presentation with the control stick of the HTC Vive (Figure 5.59).

The same group member accidentally hit the screen of Laptop 1 with the control stick of the HTC Vive as well (Figure 5.60).

Figure 5.57 : Screenshots from the VR scenes submitted for the third preliminary jury.

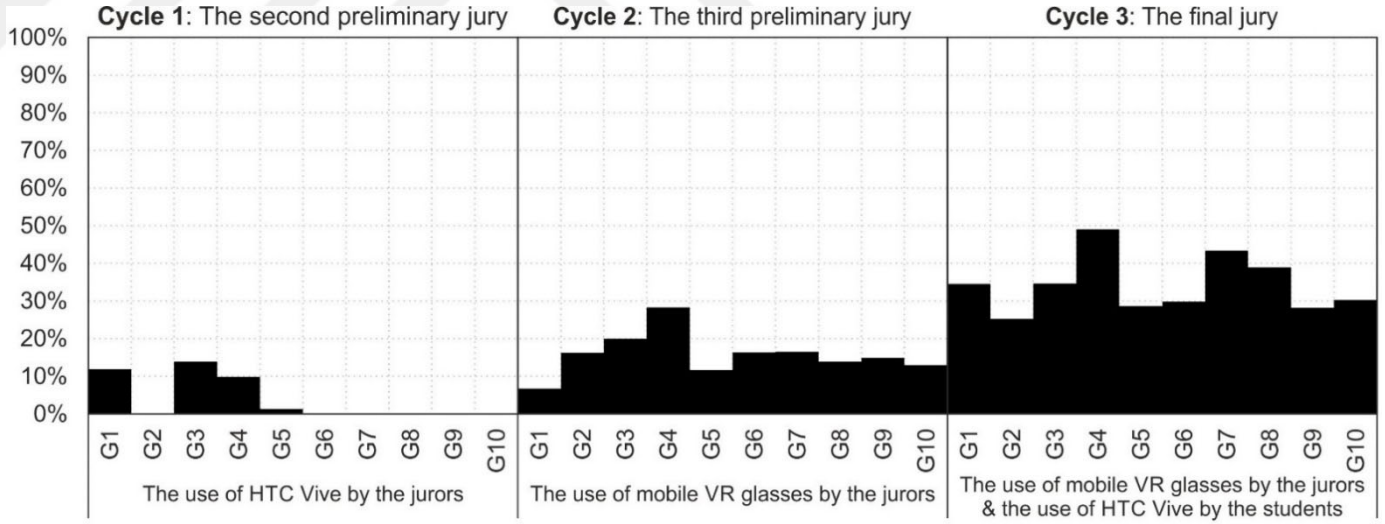


Figure 5.58 : The ratio of the durations of VR use in the jury sessions of the groups to the total jury duration of the groups.

Table 5.21 : Jury durations of the project groups and the durations of VR use of groups and jurors during the jury sessions in the final jury.

Project Group	Jury Duration	Duration of VR use of the group	Duration of experiencing the VR scene by the juror				
			Juror 1	Juror 2	Juror 3	Juror 4	Juror 5
Group 1	1152s (19m 12s)	512s (8m 32s)	40s	–	–	–	55s
Group 2	1166s (19m 26s)	238s (3m 58s)	35s + 13s	41s	–	16s	6s + 19s + 12s + 15s
Group 3	1878s (31m 18s)	996s (16m 36s)	The VR scene of this group could not be run on the smartphones.				
Group 4	1196s (19m 56s)	904s (15m 4s)	84s	–	24s + 13s + 38s	2s + 8s + 20s + 3s + 14s + 10s + 4s + 9s + 8s	17s + 53s + 13s
Group 5	1219s (20m 19s)	327s (5m 27s)	–	–	4s	77s	85s
Group 6	1296s (21m 36s)	288s (4m 48s)	38s + 2s	21s + 25s	32s + 2s + 25s + 6s + 20s	31s + 8s	12s + 29s + 11s + 14s + 20s + 10s + 10s + 19s + 12s
Group 7	1627 s (27m 7s)	1105s (18m 25s)	25s	–	50s + 21s	28s	25s + 29s + 22s + 14s
Group 8	1174s (19m 34s)	527s (8m 47s)	95s	6s +35s	73s + 5s	11s + 10s	65s
Group 9	1004s (16m 44s)	306s (5m 6s)	19s + 8s + 15s + 2s	–	3s	–	43s + 2s
Group 10	1082s (18m 2s)	219s (3m 39s)	78s	–	54s + 20s	38s	66s + 54s + 14s

m: minute(s), **s:** second(s).

Figure 5.59 : A photo showing how the group member in the VR environment tapped accidentally on the arm of his group mate who is giving the oral presentation with the control stick of the HTC Vive.

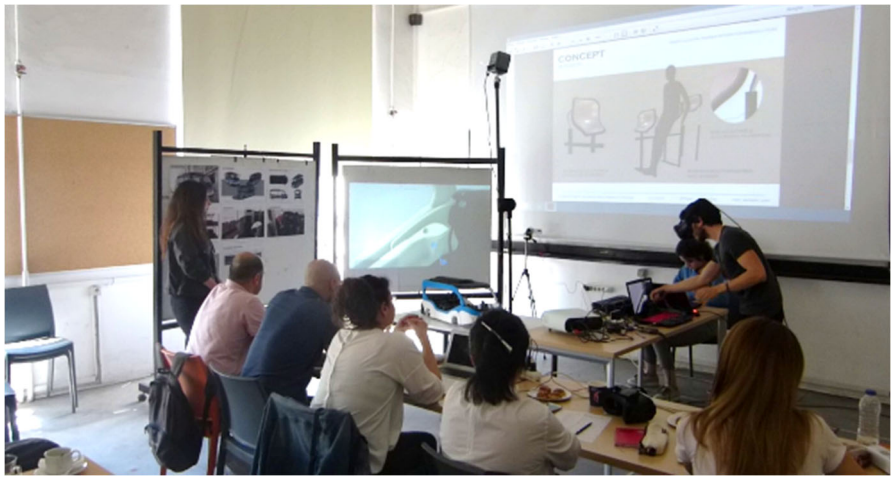


Figure 5.60 : A photo showing how the group member in the VR environment accidentally hit the screen of Laptop 1 with the control stick of the HTC Vive.

Observation 9. Group 5 used actively their 1/10 physical model in their presentation as well (Figure 5.61).

Figure 5.61 : A photo showing the use of the 1/10 scale physical model by Group 5 for presentation purposes.

Observation 10. Group 8 and Group 9 used actively their 1/1 physical mock-ups in their presentations as well (Figure 5.62).

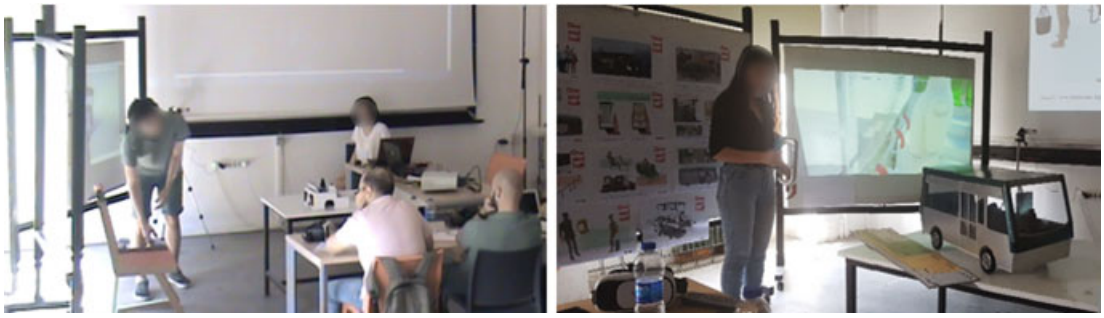


Figure 5.62 : Photos showing the use of the 1/1 scale physical mock-ups by Group 8 and 9 for presentation purposes.

Figure 5.63 : Photos showing how the 1/10 scale physical models of Group 3, 5, and 7 were examined by the jurors.

Observation 11. The 1/10 scale physical models of Group 3, 5, and 7 were examined closely by at least one juror (Figure 5.63).

Observation 12. The 1/1 scale physical mock-ups of Group 3 and Group 8 were examined closely by at least one juror (Figure 5.64).

Figure 5.64 : Photos showing how the 1/1 scale physical mock-ups of Group 3 and 8 were examined by the jurors.

(b) Interviews

In the following days after the jury session, the third-round interviews were both held with the students and the jury members who were also the instructors of the course. The interviews with the students were held as group interviews, whereas the interviews with the instructor-jurors (Juror 1, 2, and 3) were held one-to-one. Since it was not possible to hold face-to-face interviews with the invited jury members (Juror 4 and 5), their opinions were tried to be gotten via e-mail. Regarding the use way of VR in the final jury session, the questions presented in Table 5.22 were asked to students and jurors.

Outcomes of the third-round interviews

The analysis results of the transcriptions of the interviews' records showed that

1. The proposed way of VR use in the third cycle was evaluated as a better way than the previous one and was considered as well-integrated into the jury practice by the jurors and the students except for S3.1 and S3.2 (Table F.20 and Table F.21 in Appendix F).

   The responses of S3.1 and S3.2 were identified as negative cases. Therefore, both the video recordings of the final jury session and the full texts of the transcriptions were revisited to seek why they think so. And it was seen that during their final jury session, S3.2 wore the HTC Vive VR headset and entered

Table 5.22 : Questions asked to jurors and students in the third-round interviews.

	Questions asked to jurors		Questions asked to students
1	Would you evaluate the way of VR use in this jury session comparatively with the way of VR use in the previous jury session?	**1**	Would you evaluate the way of VR use in this jury session comparatively with the way of VR use in the previous jury session?
2	Was VR able to get integrated into the jury practice in the final jury session? If not, why?	**2**	Was VR able to get integrated into the jury practice in the final jury session? If not why?
3	Unlike the previous ones, students tried to make use of the physical models in their presentations as well in this jury session. What do you think about this?	**3**	Unlike the previous ones, you tried to make use of the physical models as well in your presentations in this jury session. What do you think about this?
		4	In this jury session, again, while a jury member was experiencing your VR scene by using the mobile VR glasses, you could not see what s/he saw and/or where s/he looked in your VR scene. However, this time, you were able to make your presentation by showing the design details/decisions over their virtual model in the VR scene. In this case, did you still wonder what s/he saw and/or where s/he looked in your VR scene? If did, why?

into the VR environment, and then tried to show what was being mentioned at that moment while S3.1 was giving an oral presentation, but sometimes failed to catch up with S3.1. So, some synchronization problems occurred between S3.1 and S3.2 during their presentation session, and this situation negatively affected their responses:

> Because of inexperience, our presentation was not so good in the final jury session, and we could not convey the information to the jurors very well. It would be much better if we had presented with VR in previous jury sessions. So, in the last jury session, yes, there was an image from the VR scene there. S3.2 was showing some things in the VR environment. S/he was showing the things I was talking about, but I am used to explaining it with the sheets and I only know presenting in this way. And, yes, you allowed us to practice VR for making a presentation with it, but we did not do such an exercise. That's why I presented our project only via the sheets. (S3.1, taken from the transcription of the third-round interview records)

2. The 1/10 scale physical models in the final jury session were considered “unnecessary” and “useless” by most of the jurors and students because VR was used. On the other hand, the 1/1 scale physical mock-ups of some parts of the designs were found useful (Table F.22 in Appendix F).
3. Without depending on being given feedback verbally by the jurors, the use of the HTC Vive by the students for presentation purposes with a projector projecting its VR screen onto a board eliminated the curiosity of some of the students about what a juror saw and/or where s/he looked in the VR scene while s/he was experiencing that VR scene by using the mobile VR glasses. However, it did not eliminate the curiosity of some other students in the cases not being given any verbal feedback about what was seen in the VR scene by the juror who experienced that VR scene. Apart from these, some of the students wondered whether the mobile VR glasses could be used by the jurors the same as the HTC Vive (Table F.23 in Appendix F).

Reflect: reflecting on the findings of the 3rd cycle of mandatory use

1. VR was able to be integrated into the jury practice of industrial design education to a remarkable degree.
2. The area reserved for VR presentations was left a little bit small, and this situation caused minor accidents to happen in the jury session of Group 4. Although it was not considered a big problem by the participants, it could cause damaging accidents as well. So, it should be noted the requirement of a larger and safe area for VR presentations in the final proposal for the use of VR in the jury practice.
3. Although one of the 1/10 scale physical models was actively used for presentation purposes and three of them were closely examined by one or two jurors, the 1/10 scale physical models were considered as “unnecessary” and “useless” by most of the jurors and students. On the other hand, although only four groups submitted the 1/1 scale physical mock-ups of some parts of their designs and only two of them actively used for presentation purposes and only two of them were examined closely by the jurors, these 1/1 scale physical mock-ups that represent some parts of the designs were found useful.

4. The issue of not seeing what a juror saw or where s/he looked in the VR scene while experiencing a VR scene by using the mobile VR glasses could not be eliminated with the available means. Therefore, students kept desiring to see what jurors saw or where they looked in the VR scenes while experiencing them. However, this desire of some students decreased when they showed their VR scenes by projecting on a wall with the help of a projector and disappeared when they got verbal feedback from the jurors regarding what they saw or where they looked in the VR scenes.

5.2.6 Voluntary use of VR in other practices

This part of the research aims to get clues about how VR can be integrated into the other practices of industrial design education by observing and questioning the voluntary use of VR in the educational setting of an industrial design studio course. How this part was planned and conducted is presented below.

5.2.6.1 Plan: planning the voluntary use of VR

The steps of this part were planned as follows:

1. Make VR available for students and instructors in the educational setting of the course, then
2. Observe whether it will be used by instructors and students in other studio-based practices throughout the project process,
3. If it is used, question how and why it is used based on observations.

5.2.6.2 Act: making VR available for students and instructors

Making VR technology available was considered as making it accessible and teaching how it will be used. In the lesson on February 20, 2018 (the first lesson of Week 3), the VR hardware and software to be used within the research were introduced and taught by the researcher with a three-hour presentation and demonstration (Figure 5.36). This presentation and demonstration session has already been presented previously in the section “5.2.4 Integration of the research process into the project process”.

After this training session, it was reminded that the VR equipment would be available during studio hours throughout the project process, and they could use it for any

purpose without getting permission. Then, the VR equipment was kept in the studio during the studio hours throughout the project process, and when it was demanded to be used, it was installed and made ready to use.

5.2.6.3 Observe: questioning what happened throughout the project process

Observation 1. On March 13, 2018, a very-low detail CAD model of one of the existing minibuses of the firm was shared with students and instructors by the firm so that they could imagine the borders and the volume of the interior of a minibus and get the dimensions of it (Figure 5.65).

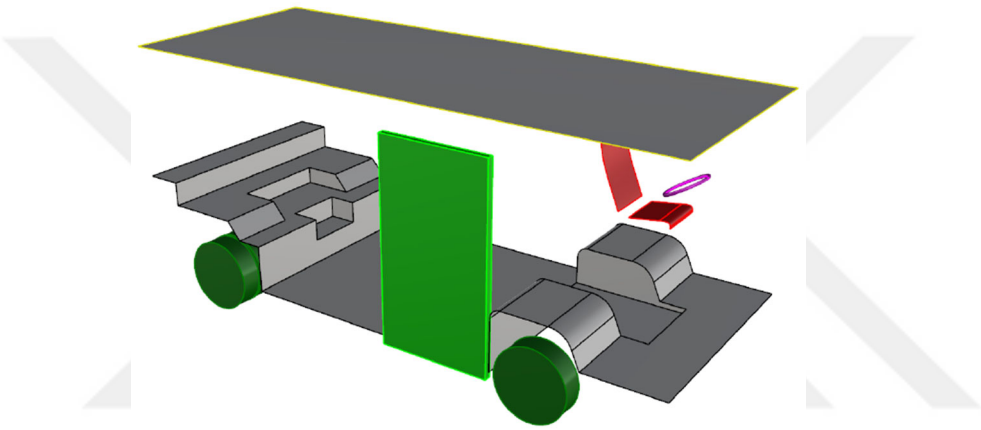


Figure 5.65 : A screenshot from the CAD model shared with students and instructors by the firm.

In the lesson on March 20, 2018 (the first lesson of Week 7 – before the first mandatory use of VR in a jury session), students and instructors drew the borders of the interior of that minibus on the ground of the studio by using the tape drawing method and based on the dimensions gotten from the CAD model. And then, using the role-playing method and some stuff such as chairs and a wheel, they tried to imagine and apprehend the borders and the volume of a minibus interior (Figure 5.66). Although they had the opportunity of using VR to apprehend the borders of that minibus by converting its CAD model into a VR scene since its CAD model existed, they did not use VR.

Observation 2. The project process was conducted via only desk critiques except for the jury sessions. Although, after the second preliminary jury session, each group had a CAD model of their design and these CAD models were used in some of these desk-critique sessions (Figure 5.67), no demand came from instructors and students to carry out those critique sessions by using VR.

Figure 5.66 : Some photos showing how students and instructors tried to imagine and apprehend the borders of the interior of a minibus by using tape drawing and role-playing methods.

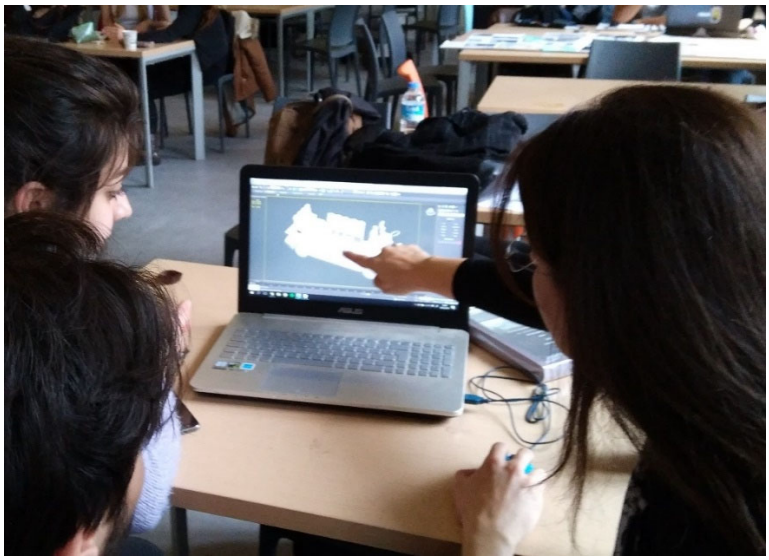


Figure 5.67 : An example of the desk-critique sessions carried out by using CAD models.

Observation 3. Throughout the project process, students demanded to use VR four times in total:

- The first demand came from Group 2 and Group 3 in the lesson on April 3, 2018 (the first lesson of Week 9 – just before the first mandatory use of VR in a jury session).
- The second demand came from Group 3, Group 5, and Group 6 in the lesson on April 20, 2018 (the second lesson of Week 11 – between the second and third preliminary jury sessions).
- The third demand came from S1.1, S2.1, S4.1, and Group 3 in the lesson on May 15, 2018 (the first lesson of Week 15 – the last week of the semester).
- The fourth demand came from Group 6, Group 10, and S4.1 in the lesson on May 18, 2018 (the second lesson of Week 15 – the last week of the semester).

All of these demands that came from students were mainly based on evaluating their design decisions on a 1/1 scale and in a realistic way as much as possible – either individually or together with their group members. In the third and fourth demands, the motivation of being prepared for the final jury presentation accompanied the motivation of evaluating design decisions. Some photos showing how the VR setup was used by students in these lessons are presented in Figure 5.68.

Other students preferred to use the desktop VR mode of SimLab Composer 8.0 to evaluate their design decisions and/or to be prepared for their final jury presentations.

Figure 5.68 : Some photos showing how the HTC Vive VR setup was used by students.

Observation 4. While using VR, students tried to eliminate the lack of physical interaction with the seating units and grab bars in their virtual models by using a chair and a plastic pipe (Figure 5.69).

5.2.6.4 Reflect: reflecting on the findings of the voluntary use of VR

To make VR available in the studio environment of an industrial design studio course and give a short training on how to use its hardware and software opened the way of using it as a design evaluation tool by students. However, neither students nor instructors demanded or attempted to use VR neither while performing the activities to imagine and apprehend the borders of an existing minibus nor while critiquing the design decisions together in the desk-critique sessions.

5.3 Third Stage: Final Investigations

In the new situation that was emerged by intervening in the educational setting of an industrial design studio course with VR, the integration of VR into the jury practice was achieved to a certain extent by the proposed way of VR use in the final jury session

Figure 5.69 : Some photos showing how students tried to eliminate the shortage of physical interaction with the seating unit and grab bars in their virtual model.

where VR was used by the students for design representation and presentation purposes and by the jurors for design evaluation purposes. On the other hand, it was used by students – either individually or together with their group members – during the studio hours of the course to evaluate their design decisions on a 1/1 scale and in a realistic way as much as possible. However, it was not used in other practices and activities where students and instructors got involved together. Based on this situation, final investigations were conducted

— to measure the usability level of the proposed way of VR use in the final jury session,

— to reveal the final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design, and

— to question why VR was not used in other practices and activities where students and instructors got involved together.

For these purposes, a questionnaire-based study and interviews with the user groups were conducted. The questionnaire was used to measure the usability level of the proposed way of VR use in the final jury session and collect quantitative data about the final assessments of students and instructors on the VR technology they used during the project process and its use in industrial design studio courses. The interviews were carried out to collect qualitative data about the final assessments of students and instructors on the VR technology they used during the project process and its use in industrial design studio courses and question why VR was not used in other practices and activities where students and instructors got involved together. Besides, the questionnaire was also used for revealing whether participants had any previous familiarity with the technology used in this research. This section presents how these investigations are conducted and their results.

5.3.1 Familiarity with the technology used in this research

In the course process, instructors and invited jury members both used the HTC Vive VR headset and the VR Box mobile VR glasses, whereas students used only the HTC Vive VR headset. Students also used SimLab software to prepare VR scenes and to test these scenes or to evaluate their designs by running its desktop VR mode. Therefore, the questions related to technology familiarity were prepared in line with this situation and were asked as presented in Table 5.23 with a 5-point Likert scale ranging from not at all familiar to extremely familiar (1 = “not at all familiar” – 7 = “extremely familiar”).

The responses of participants to these questions (Figure 5.70) showed that

— 1 instructor had no familiarity with the HTC Vive headset, VR Box mobile VR glasses, and similar technologies,

— 2 instructors had low familiarity with the HTC Vive headset, VR Box mobile VR glasses, and similar technologies,

— 2 invited jury members had high familiarity with the HTC Vive headset, VR Box mobile VR glasses, and similar technologies,

— 22 students had no familiarity with the HTC Vive headset and similar technologies,

— 6 students had low familiarity with the HTC Vive headset and similar technologies,

— 26 students had no familiarity with the SimLab Composer 8.0 and similar software,

— 1 student had low familiarity with the SimLab Composer 8.0 and similar software,

— 1 student had mid-level familiarity with the SimLab Composer 8.0 and similar software,

at the beginning of the research.

Table 5.23 : Questionnaire items related to technology familiarity.

	For instructors and invited jury members		**For students**
1	How do you describe your previous familiarity status with the VR glasses and their control sticks (HTC Vive headset) that you used in the second preliminary jury session or these kinds of VR headsets?	**1**	How do you describe your previous familiarity status with the VR glasses and their control sticks (HTC Vive headset) used in the jury sessions and the studio hours or with these kinds of VR headsets?
2	How do you describe your previous familiarity status with the VR Box mobile VR glasses that you used in the third preliminary and final jury sessions or these kinds of VR glasses?	**2**	How do you describe your previous familiarity status with the SimLab Composer 8.0 used for preparing and experiencing VR scenes in this process or similar software?

It is not surprising that two invited jury members have high familiarity with the HTC Vive headset, VR Box mobile VR glasses, and similar technologies. Because, as mentioned before, VR technology has already been started to be used by professional designers in many areas of industry such as automotive, furniture, and consumer durable. On the other hand, 74% of the resident actors of the course had no previous familiarity with the HTC Vive headset and similar technologies, and the rest of them had low familiarity. Similarly, 93% of the students had no previous familiarity with the SimLab Composer 8.0 used as the intermediary software in this process. Among the students, only one had mid-level familiarity with it.

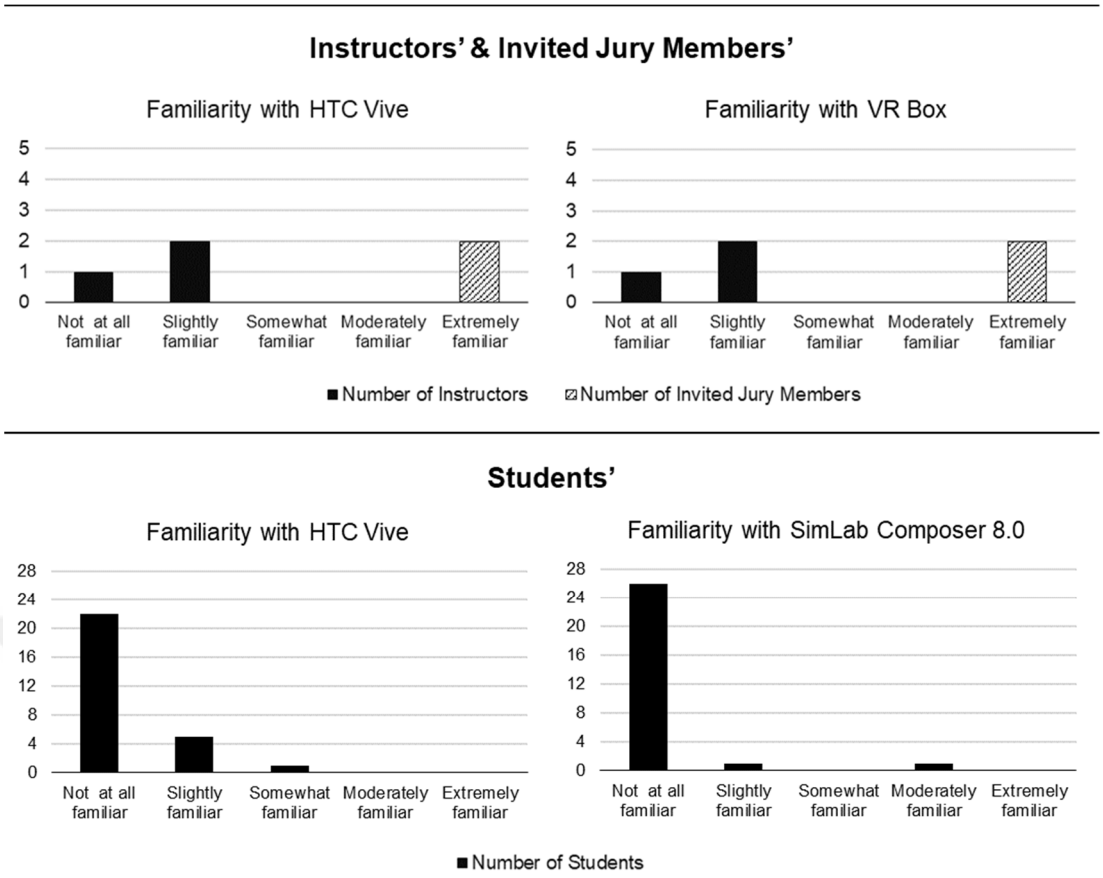


Figure 5.70 : Participants' previous familiarity status with the technology used in this research.

5.3.2 Usability level of the proposed way of VR use in the final jury session for using VR in the jury practices of industrial design education

The proposed way of VR use in the final jury session was considered as a system in which VR was used together with other representations by the students for design presentation purposes and by the jurors for design evaluation purposes. Therefore, System Usability Scale (SUS) was used to measure the usability level of this system. SUS items were adapted, and then, placed in the questionnaire. How these items were adapted is presented in Table 5.24.

SUS items are originally asked with a 5-point Likert scale. However, they can also be asked with a 7-point Likert scale in the cases the interpolations are wanted to be seen (Sauro, 2010b). In this part of the study SUS items were asked with a 7-point Likert scale ranging from strongly disagree to strongly agree (1 = "strongly disagree" – 7 = "strongly agree"). When SUS items are used with a 7-point Likert scale, the SUS score is calculated as follows:

1. Subtract one from the participant response for odd-numbered items (1,3,5,7, 9),
2. Subtract the participant responses from 7 for even-numbered items (2,4,6,8 10)
3. Add up the converted responses for each participant,
4. Multiply that total by 60/100 to convert the range of possible values from 0 to 100 (Garcia-Ruiz, 2013).

Table 5.24 : Original SUS items and how they were modified for measuring the usability level of the proposed way of VR use in the final jury session.

	Original SUS Items	**Modified SUS Items**
1	I think that I would like to use this **system** frequently.	I think that I would like to use this **system** frequently.
2	I found the **system** unnecessarily complex.	I found this **system** unnecessarily complex.
3	I thought the **system** was easy to use.	I thought this **system** was easy to use.
4	I think that I would need the support of a technical person to be able to use this **system**.	I think that I would need the support of a technical person to be able to use this **system**.
5	I found that the various functions in this **system** were well integrated.	I found that the various functions in this **system** (such as the functions of design sheets, physical models, and VR) were well integrated.
6	I thought that there was too much inconsistency in this **system**.	I thought that there was too much inconsistency in this **system**.
7	I would imagine that most people would learn to use this **system** very quickly.	I think that most people would learn to use this **system** very quickly.
8	I found the **system** very cumbersome to use.	I found the **system** very cumbersome to use.
9	I felt very confident using the **system**.	I felt very confident using this **system**.
10	I needed to learn a lot of things before I could get going with this **system**.	I needed to learn a lot of things before I could get going with this **system**.

Based on this formulation, the SUS score of the proposed way of VR use in the final jury session was calculated as 71.3. According to the curved grading scale interpretation of SUS scores (Figure 5.72) prepared by Sauro and Lewis (2016), this score corresponds to the letter grade “C +”. Although there are various interpretations of what these scores and letter grades mean in the literature, it can be said that this score and its corresponding letter grade mean that the usability of the proposed use way of VR is OK but can be improved (Thomas, n.d.).

On the other hand, when the responses to each SUS item were examined separately (Figure 5.71), it was seen that the thought that using VR in this way requires the support of a technical person (SUS4) was the thought that decreased the SUS score the most.

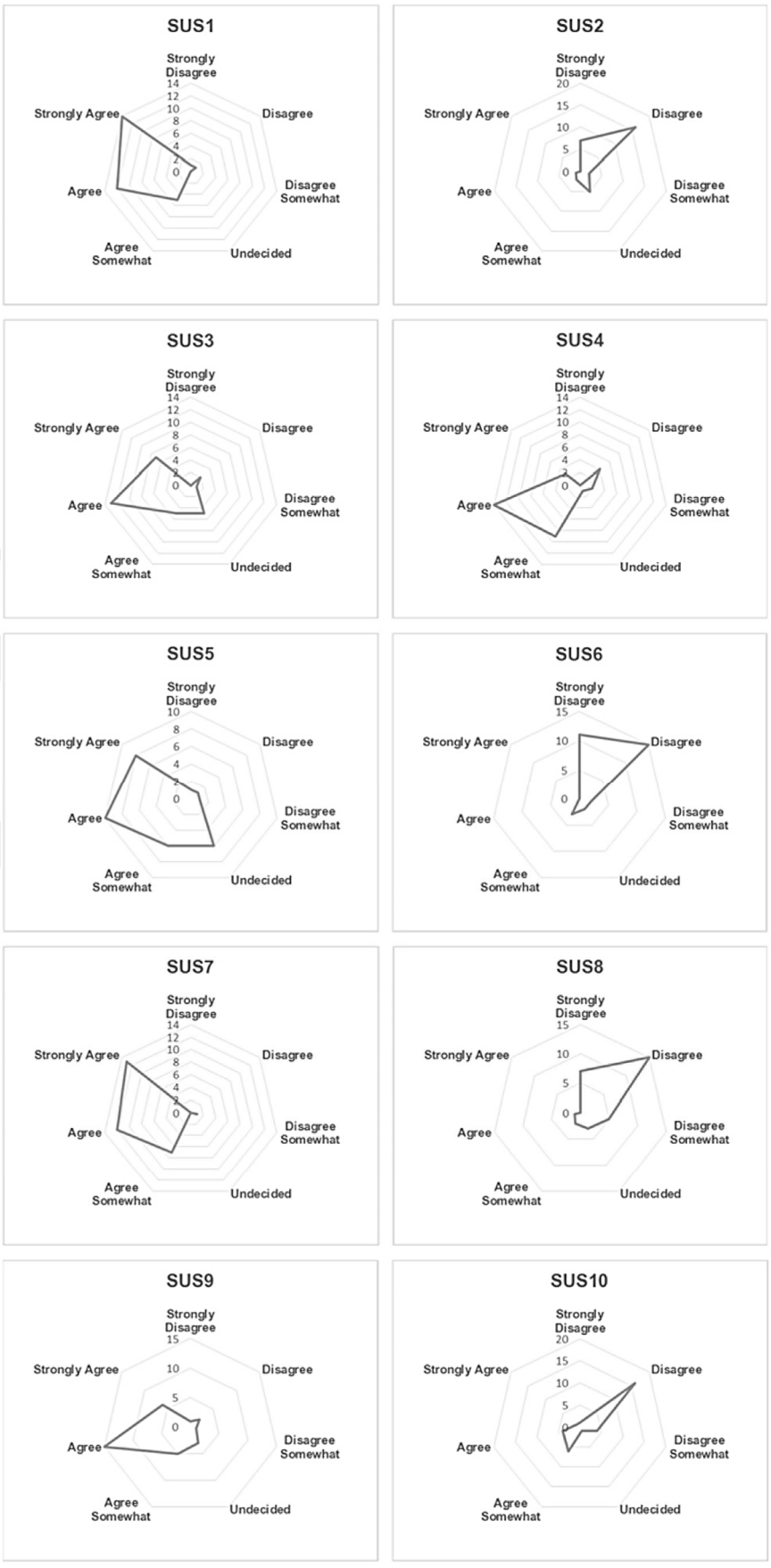


Figure 5.71 : The radar graphs of the responses to the SUS items in the questionnaire.

Table 8.5 Curved Grading Scale Interpretation of SUS Scores		
SUS Score Range	**Grade**	**Percentile Range**
84.1–100	A+	96–100
80.8–84.0	A	90–95
78.9–80.7	A−	85–89
77.2–78.8	B+	80–84
74.1–77.1	B	70–79
72.6–74.0	B−	65–69
71.1–72.5	C+	60–64
65.0 –71.0	C	41–59
62.7–64.9	C−	35–40
51.7–62.6	D	15–34
0.0–51.6	F	0–14

Figure 5.72 : Curved grading scale interpretation of SUS scores, taken from (Sauro & Lewis, 2016).

5.3.3 Final assessments of students and instructors on the VR technology they used during the project process and its use in industrial design studio courses

To reveal the final assessments of students and instructors on the VR technology they used during the project process and its use in industrial design studio courses, both quantitative and qualitative data were collected and analyzed.

The quantitative data were gathered by the 7-point Likert scale items that were adapted from the scale items of UTAUT2 and NPS and placed in the questionnaire. The reasons behind the selection of these scale items are explicitly presented in the section "5.1.2 Preliminary study", and how these items were modified for this part of the research is presented in Table 5.25. The "Performance Expectancy" and "Effort Expectancy" items of UTAUT2 were modified in line with the participants' purposes of VR use and the VR technologies used by them during the in-studio study. For this reason, there are divisions in some items. Also, different from the preliminary study, the "Facilitating Conditions" items of UTAUT2 were included in this part of the research. Because the researcher was employed as a facilitator during the in-studio study. The scale items of UTAUT2 that belong to their constructs of "Social Influence", "Price Value", and "Habit" were excluded due their not being applicable for this part of the study as well.

Table 5.25 : Original items of UTAUT2 and NPS and how they were modified for this part of the research.

	Original items	Modified items for instructors		Modified items for students	
PE1	I find mobile Internet useful in my daily life.	**PE1.1**	I found VR technology useful for the jury practices of industrial design education.	**PE1.2**	I found VR technology useful for evaluating our design ideas individually or together with our group members.
PE2	Using mobile Internet helps me accomplish things more quickly.	**PE2.1**	Using VR technology helps me understand and evaluate students' design ideas more quickly.	**PE2.1**	Using VR technology helps us convey and explain our design ideas more quickly.
				PE2.2	Using VR technology helps us evaluate our design ideas more quickly.
PE3	Using mobile Internet increases my productivity.	**PE3**	Using VR technology increased my productivity.		
EE1	Learning how to use mobile Internet is easy for me.	**EE1.1**	Learning how to use the VR headset (HTC Vive) was easy for me.		
		EE1.2	Learning how to use the mobile VR glasses (VR Box) was easy for me.	**EE1.2**	Learning how to use the intermediary software (SimLab Composer 8.0) was easy for me.
EE2	My interaction with mobile Internet is clear and understandable.	**EE2.1**	My interaction with the VR headset (HTC Vive) was clear and understandable.		
		EE2.2	My interaction with the mobile VR glasses (VR Box) was clear and understandable.	**EE2.2**	My interaction with the intermediary software (SimLab Composer 8.0) was clear and understandable.
EE3	I find mobile Internet easy to use.	**EE3.1**	I think using the VR headset (HTC Vive) is easy to use.		
		EE3.2	I think using the mobile VR glasses (VR Box) is easy to use.	**EE3.2**	I think using the intermediary software (SimLab Composer 8.0) is easy to use.
EE4	It is easy for me to become skillful at using mobile Internet.	**EE4.1**	I think it will be easy for me to become skillful at using these kinds of VR headsets.		
		EE4.2	I think it will be easy for me to become skillful at using these kinds of mobile VR glasses.	**EE4.2**	I think it will be easy for me to become skillful at using these kinds of software.

PE: Performance Expectancy, **EE:** Effort Expectancy, **FC:** Facilitating Conditions, **HM:** Hedonic Motivation, **BI:** Behavioral Intention, **NPS:** Net Promoter Score

Table 5.25 (continued) : Original items of UTAUT2 and NPS and how they were modified for this part of the research.

	Original items	Modified items for instructors	Modified items for students
FC1	I have the knowledge necessary to use mobile Internet.	**FC1** I think I have the knowledge necessary to use VR technology now.	
FC2	Mobile Internet is compatible with other technologies I use.	**FC2** I think VR technology is compatible with other technologies I use.	
FC3	I can get help from others when I have difficulties using mobile Internet.	**FC3** I think there is someone I can get help from when I have difficulties using VR technology.	
FC4	I have the resources necessary to use mobile Internet.	**FC4** I think I have the resources necessary to use VR technology.	
HM1	Using mobile Internet is fun.	**HM** Using VR technology is fun/ enjoyable/ entertaining.	
HM2	Using mobile Internet is enjoyable.		
HM3	Using mobile Internet is very entertaining.		
BI1	I intend to continue using mobile Internet in the future.	**BI1** I intend to continue using VR technology in the future.	
BI2	I will always try to use mobile Internet in my daily life.	**BI2** I will always try to use VR technology in industrial design studio courses.	
BI3	I plan to continue to use mobile Internet frequently.	**BI3** I plan to use VR technology frequently in industrial design studio courses.	
NPS	How likely is it that you would recommend our company to a friend or colleague?	**NPS** On a scale of 0 to 10, how likely is it that you would recommend this VR technology to a friend or colleague for using it in industrial design studio courses?	

PE: Performance Expectancy, **EE:** Effort Expectancy, **FC:** Facilitating Conditions, **HM:** Hedonic Motivation, **BI:** Behavioral Intention, **NPS:** Net Promoter Score

According to the graphical representations of the results presented in Figure 5.73, Figure 5.74, Figure 5.75, and Figure 5.76, in terms of *Performance Expectancy (PE)*,

- all students and instructors found using VR technology useful in the jury practices of industrial design education. On the other hand, 23 out of 28 students found it also useful for evaluating their design ideas individually or together with their group members. (Figure 5.73).
- 27 out of 28 students think that using VR technology helps them convey and explain their design ideas more quickly, whereas instructors think that using VR technology helps them understand and evaluate students' design ideas more quickly. Additionally, 25 out of 28 students think that using VR technology also helps them evaluate their design ideas more quickly (Figure 5.73).
- instructors and 25 out of 28 students think that using VR technology increased their productivity (Figure 5.73).

In terms of *Effort Expectancy (EE)*,

- instructors and 24 out of 28 students think that learning how to use the VR headset (HTC Vive) was easy for them (Figure 5.74).
- instructors and 25 out of 28 students think that their interactions with the VR headset (HTC Vive) were clear and understandable (Figure 5.74).
- instructors and 26 out of 28 students think that using the VR headset (HTC Vive) is easy to use (Figure 5.74).
- instructors and 23 out of 28 students think that becoming skillful at using these kinds of VR headsets will be easy for them (Figure 5.74).

Instructors also think that

- learning how to use the mobile VR glasses (VR Box) was easy for them (Figure 5.74).
- their interactions with the mobile VR glasses (VR Box) were clear and understandable (Figure 5.74).
- using the mobile VR glasses (VR Box) is easy to use (Figure 5.74).

— becoming skillful at using these kinds of mobile VR glasses will be easy for them (Figure 5.74).

On the other hand,

— 23 out of 28 students think that learning how to use the intermediary software (SimLab Composer 8.0) was easy for them (Figure 5.74).

— 20 out of 28 students think that their interactions with the intermediary software (SimLab Composer 8.0) were clear and understandable (Figure 5.74).

— 26 out of 28 students think that using the intermediary software (SimLab Composer 8.0) is easy to use (Figure 5.74).

— 24 out of 28 students think that becoming skillful at using these kinds of software will be easy for them (Figure 5.74).

In terms of *Facilitating Conditions (FC)*,

— instructors and 8 out of 28 students think that they now have the knowledge to a certain degree that is necessary to use VR technology, whereas 12 out of 28 students think that they now have the knowledge necessary to use VR technology (Figure 5.75).

— 1 instructor and 5 out of 28 students think that VR technology is compatible with other technologies they use to a certain degree, whereas 2 instructors and 19 out of 28 students think that VR technology is compatible with other technologies they use (Figure 5.75).

— instructors and 26 out of 28 students think that from now on, there is someone they can get help from when they have difficulties using VR technology (Figure 5.75).

However,

— only 8 out of 28 students reported that they have the resources necessary to use VR technology (Figure 5.75),

— 1 instructor and 12 out of 28 students reported that they have some of the resources necessary to use VR technology (Figure 5.75), and

— 2 instructors and 4 out of 28 students reported that they do not have the resources necessary to use VR technology (Figure 5.75).

In terms of *Hedonic Motivation (HM)*, instructors and 26 out of 28 students think that using VR technology is fun/ enjoyable/ entertaining (Figure 5.76).

In terms of *Behavioral Intention (BI)*,

— 1 instructor and 17 out of 28 students reported that they intend to continue using VR technology in industrial design studio courses, whereas 1 instructor and 6 out of 28 students reported that they intend to continue using VR technology in industrial design studio courses to some extent. 1 instructor and 5 out of 28 students reported that they are not sure whether they have an intention to continue using VR technology in industrial design studio courses (Figure 5.76).

— 1 instructor and 13 out of 28 students reported that they will always try to use VR technology in industrial design studio courses, whereas 1 instructor and 10 out of 28 students reported that they will try to use VR technology to some extent in industrial design studio courses. 1 instructor and 5 out of 28 students reported that they are not sure whether they will try to use VR technology in industrial design studio courses (Figure 5.76).

— 1 instructor and 16 out of 28 students reported that they plan to use VR technology frequently in industrial design studio courses, whereas 1 instructor and 7 students reported that they plan to use VR technology to some extent in industrial design studio courses. 1 instructor and 3 out of 28 students reported that they are not sure whether they plan to use VR technology frequently in industrial design studio courses, whereas 2 students reported that they do not plan to use VR technology frequently in industrial design studio courses (Figure 5.76).

On the other hand, instructors' and students' responses to the Net Promoter Score item were evaluated together (Figure 5.77), and NPS was calculated as 65. Although there are various interpretations on how to interpret net promoter scores in the literature, it can be said that this score is sufficient, and most of the participants tend to recommend VR technology to their friends or colleagues for using it in industrial design studio courses.

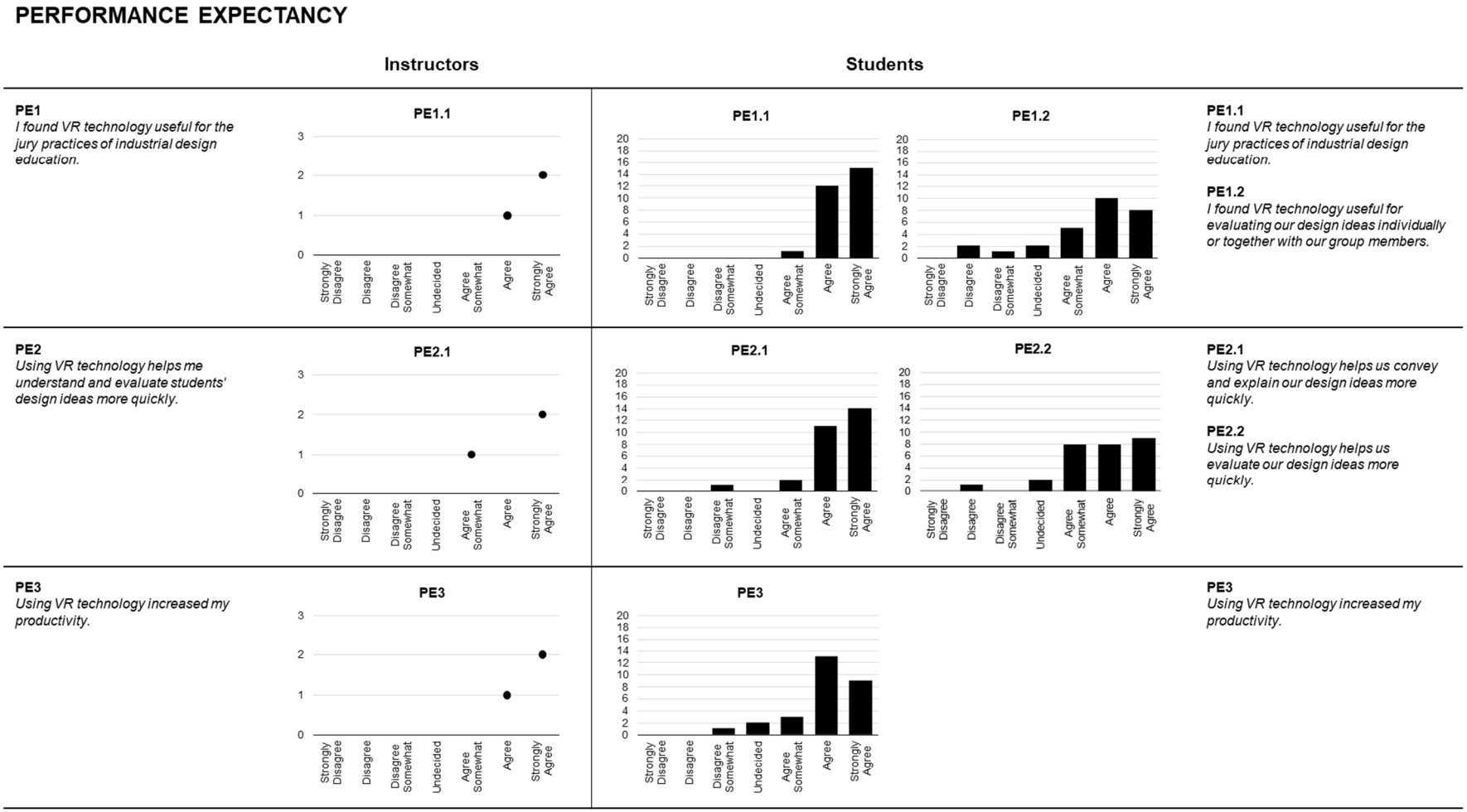


Figure 5.73 : The graphical representations of the responses to Performance Expectancy items.

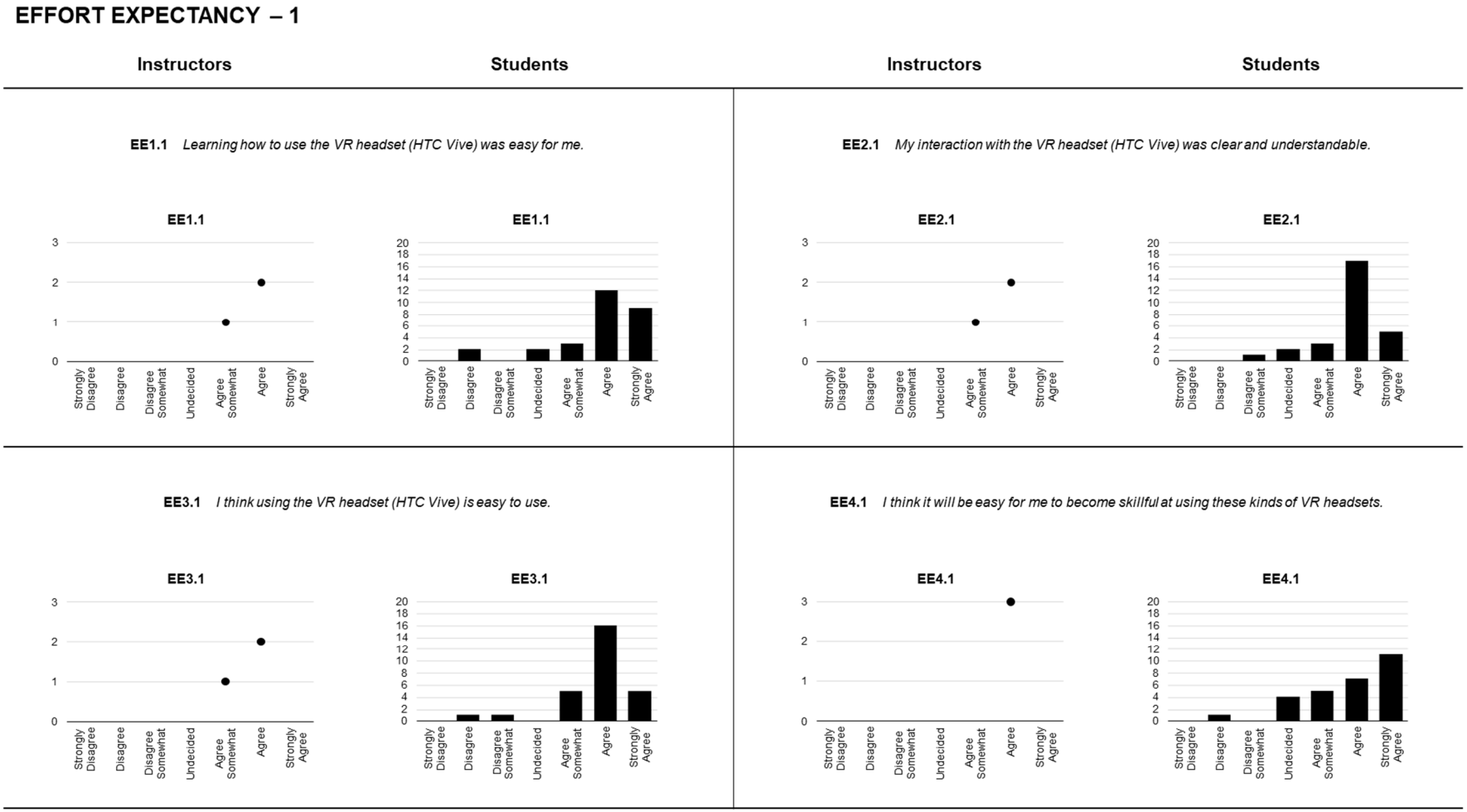


Figure 5.74 : The graphical representations of the responses to Effort Expectancy items.

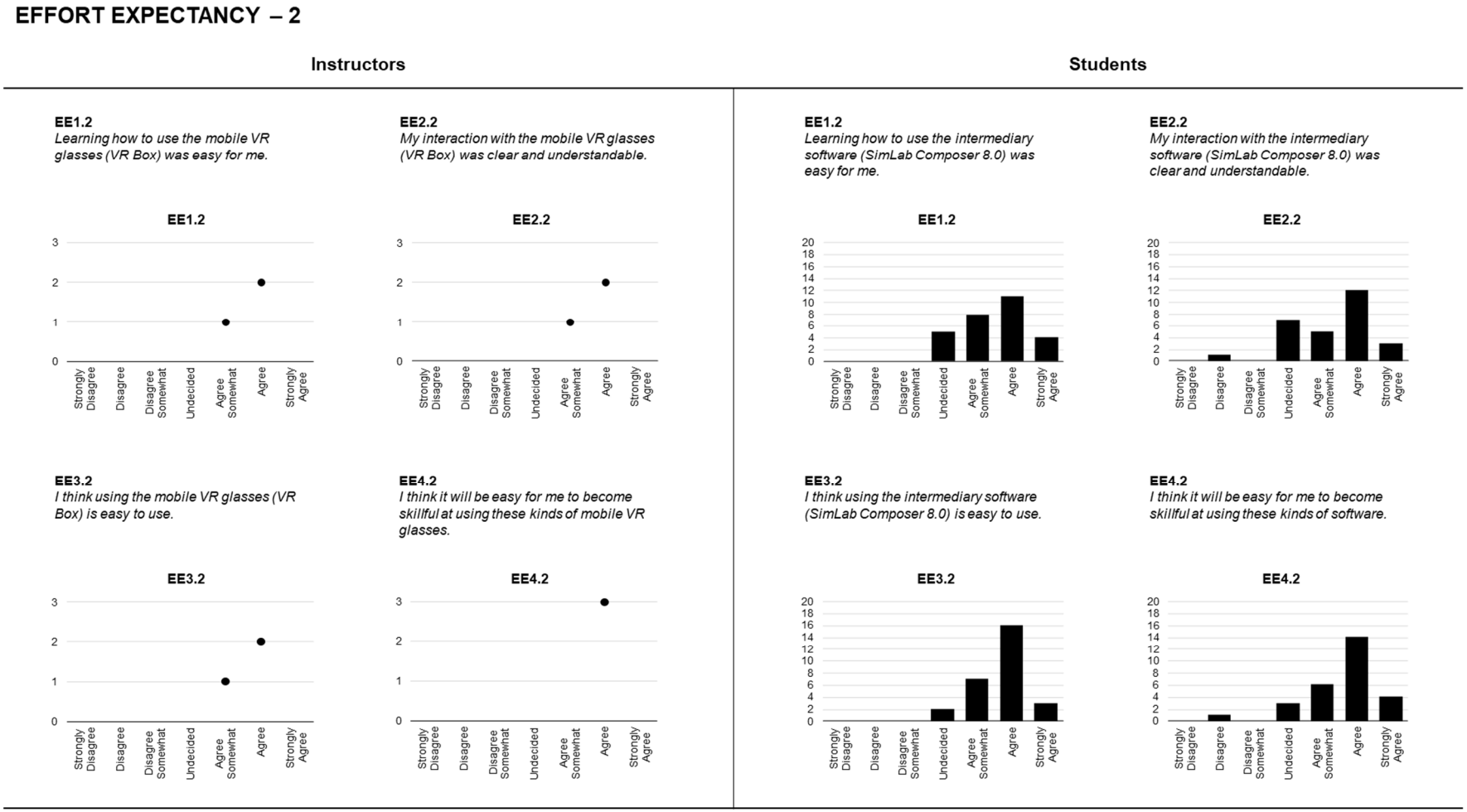


Figure 5.74 (continued): The graphical representations of the responses to Effort Expectancy items.

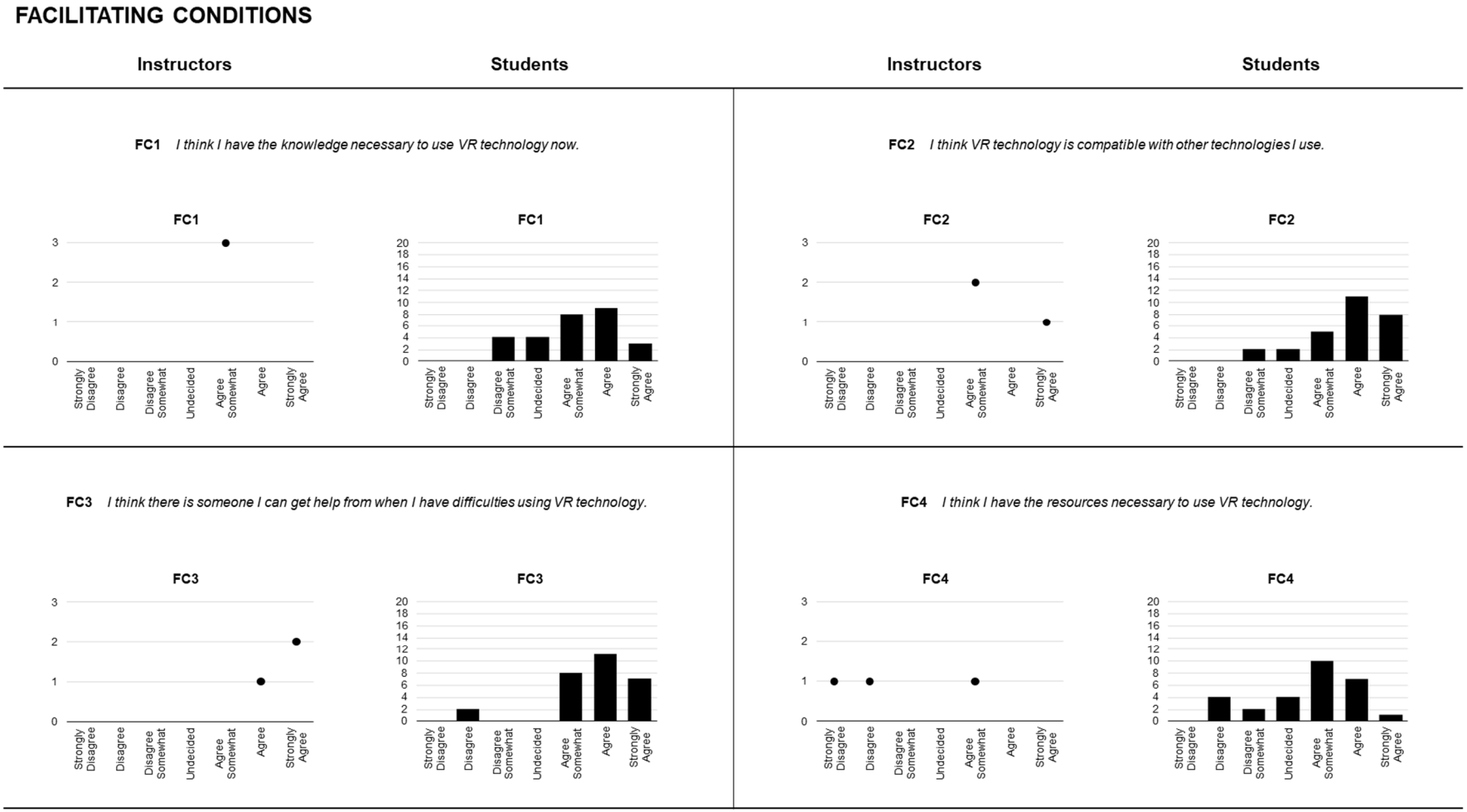


Figure 5.75 : The graphical representations of the responses to Facilitating Conditions items.

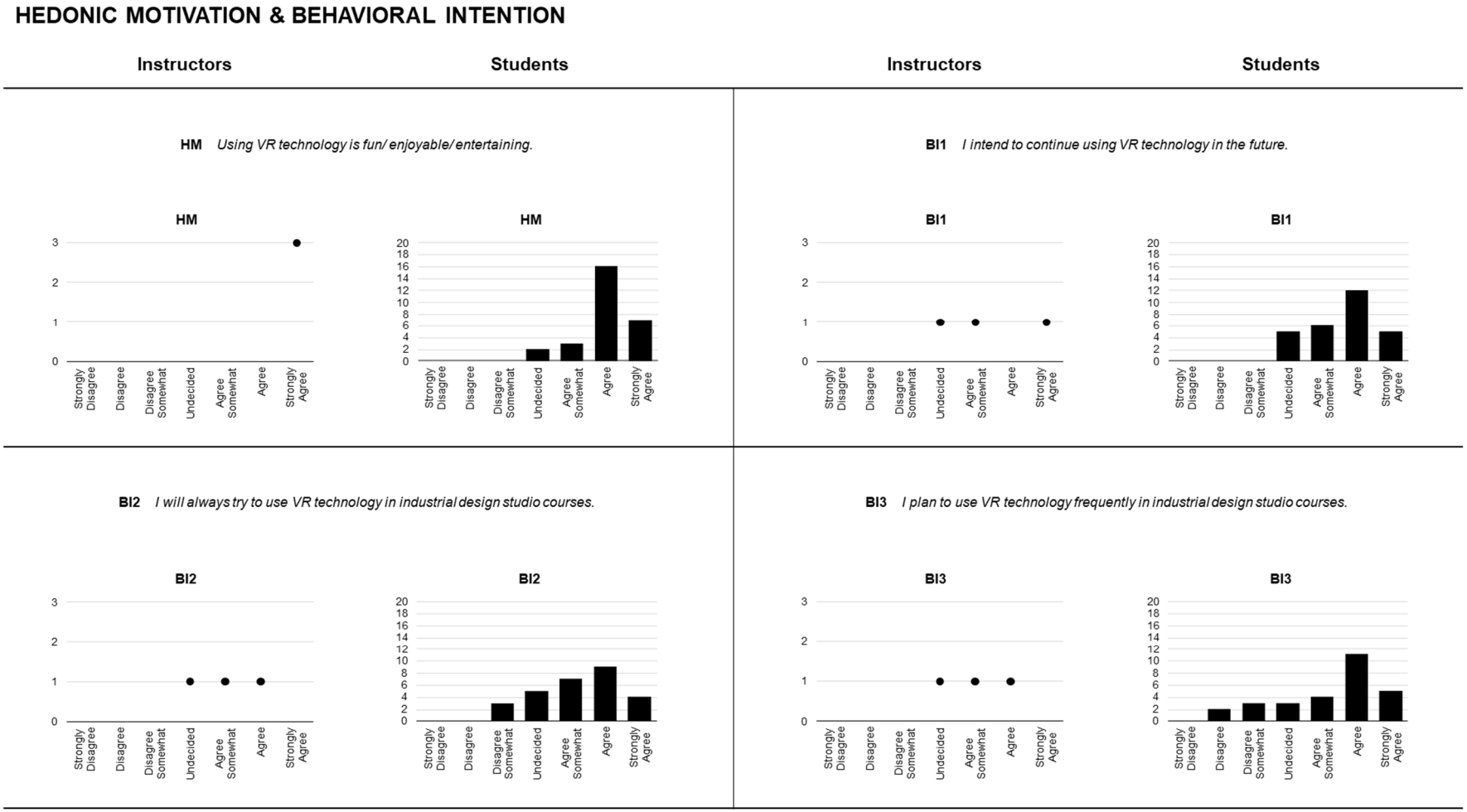


Figure 5.76 : The graphical representations of the responses to Hedonic Motivation and Behavioral Intention items.

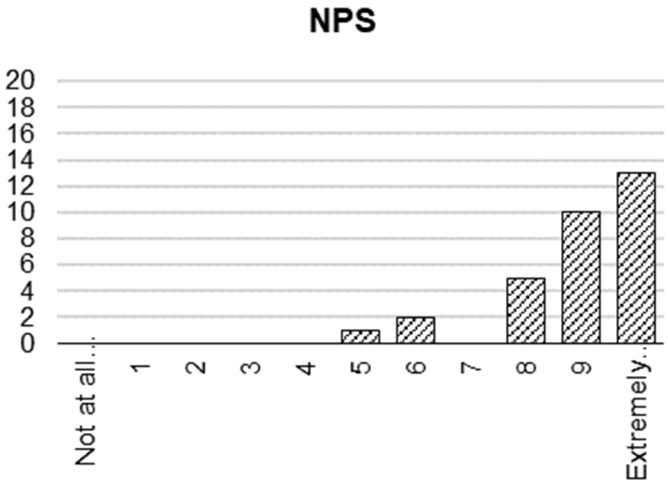


Figure 5.77 : The graphical representation of participants' responses to the Net Promoter Score item.

The qualitative data were gathered by interviews. These interviews were carried out with the students as group interviews and with the instructors one-to-one. In these semi-structured interviews, opening questions were as follows:

- What do you think about this course/project process where VR technology was used, and how do you describe your experience of using VR technology during this process?
- What do you think about VR technology and using it in industrial design studio courses? What are your positive and negative opinions in this context?
- What do you think about the sustainability of using VR technology in industrial design studio courses?

All interviews were recorded by a video camera and a voice recorder. These records were transcribed by the researcher. Then, the transcriptions were analyzed by the content analysis method that was described in detail in the section "5.1.2 Preliminary study". As a result of the analysis, the revealed assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design are as follows:

In terms of "Design Communication":

VR

- *improved/improves design communication not only between instructors and designs but also between instructors and students* (I1, I2, S8.2).

In terms of “Design Representation”:

VR is

— *the live representation of a design* (I1, S3.3, S5.3),

— *the most realistic representation of a design (compared to design sheets and scaled physical models)* (I1, S1.2, S2.2, S2.3, S7.3, S10.1, S10.2),

— *useful for representing so big designs that making their physical prototypes and models is too hard or impossible* (S2.2, S3.1, S3.2, S3.3, S5.3, S6.1, S8.2).

VR

— *decreased/decreases the need for physical models in the juries* (S1.1, S1.2, S1.4, S2.1, S2.2, S2.3, S3.1, S3.2, S3.3, S4.1, S4.2, S4.3, S5.1, S5.3, S7.1, S7.2, S7.3, S8.2, S8.3, S9.1, S9.2),

— *decreased/decreases the need for both design sheets and physical models in the juries* (I2, S6.2, S6.3, S10.1).

However, VR

— *did not/does not eliminate the need for physical models or mock-ups* (I1, I3, S2.1, S2.2, S2.3, S5.1, S6.2, S6.3),

— *did not/does not eliminate the need for design sheets* (I3, S1.1, S1.2, S1.3, S2.2, S7.1, S7.2, S7.3, S8.2, S8.3).

In terms of “Design Presentation”:

VR

— *increased/increases the quality of students' design presentations* (I1, I3),

— *attracted and held/attracts and holds the audience's attention during presentations* (I1).

Presenting designs by using VR

— *enabled/enables students not to forget what they will explain during the presentation* (S4.1, S5.2, S5.3),

— *made/makes students' work easier in the juries* (S1.2, S3.1, S4.2, S5.3, S5.3, S8.2, S8.2, S9.1, S9.2, S10.1, S10.2),

— *made/makes students feel good, safe, and self-confident in the juries* (S2.1, S2.2, S3.2, S3.3, S4.1, S5.1, S7.1, S7.2, S8.2, S8.3, S9.1, S9.2, S10.1, S10.2).

In terms of "Design Evaluation":

VR

— *enabled/enables students and instructors to get rid of the restrictions of 2D representations on design sheets* (I1, I2),

— *enabled/enables students and instructors to penetrate the 3D CAD models on a 1/1 scale* (I1, S3.1, S3.3, S4.1, S5.1, S5.3, S6.3, S7.1, S8.1, S8.2, S10.1, S10.2),

— *allowed/allows instructors to examine as much detail as they want in the way they want in CAD models* (I1),

— *enabled/enables instructors to see and understand what design details students could not explain verbally or did not mention* (I2, S8.2, S8.3, S10.1),

— *enabled/enables a more detailed and a more accurate evaluation of designs* (I1, I2, I3, S1.2, S1.3, S2.1, S2.2, S2.3, S3.1, S3.2, S3.3, S4.1, S4.2, S4.3, S5.1, S5.3, S6.3, S7.1, S8.1, S8.2, S8.3, S9.1, S10.1),

— *is useful when evaluating designs that are so big that we can get in* (I1, I2, I3, S1.1, S1.2, S1.3, S2.1, S2.2, S2.3, S3.1, S3.2, S3.3, S4.1, S4.2, S4.3, S5.1, S5.2, S5.3, S6.1, S6.2, S6.3, S7.2, S7.3, S8.1, S8.2, S8.3, S9.1, S9.2),

— *may also be useful when evaluating designs of small products* (I1, S3.3, S5.3, S8.3, S9.1),

— *is useless when evaluating designs of small products* (I2, I3, S1.1, S1.2, S1.3, S2.1, S2.2, S2.3, S3.1, S3.2, S4.3, S5.1, S5.2, S6.1, S6.2, S6.3, S7.2, S8.1, S8.2, S9.2).

In terms of "Design Process":

VR can be used

— *in design juries* (I1, I2),

— *from the moment CAD modeling begins in the design process* (I2, S2.2, S3.1, S3.2, S3.3, S4.1, S5.2, S5.3, S6.2, S6.3, S7.2, S9.1, S9.2),

— *in all phases of the design process* (I3).

VR can also be used

— *in the ideation phase of the design process* (S5.3, S7.1),

— *for experiencing existing designs – without getting them or going up to them – in the early stages of the design process if their CAD models are available* (I1, S2.2, S4.2, S4.1, S10.1, S10.2).

In terms of "Performance of Students":

VR

— *increased/increases the motivation of students* (I1, I3, S3.1, S3.3, S5.3, S8.2, S10.1, S10.2)

— *increased/increases both students' and instructors' productivity* (I1, I2),

— *increased/increases the performance of students* (I1, S2.2, S5.1),

— *forced/encouraged / forces/encourages students to produce more detailed projects and CAD models* (I1, S2.2, S3.1, S5.1, S5.3, S6.2, S7.1, S7.3, S8.1, S8.3, S9.1),

— *increased/increases the quality of students' CAD models* (I3, S2.2, S3.1, S8.3),

— *increased/increases the quality of students' projects* (I1),

— *increased/increases the students' success* (I1, S8.3).

In terms of "Competency Development of Students":

VR

— *improved/improves students' ability to criticize their own design on their own* (I1, S3.1, S3.2, S3.3, S5.1, S5.3, S6.2, S6.3, S7.1, S7.3, S8.2, S9.2, S10.1, S10.2).

In terms of "Educational Use":

VR

— *will be useful in the industrial design studio courses whose project subjects are to design products that are so big that we can get in* (I1, I2, I3, S1.1, S1.2,

S1.3, S2.1, S2.2, S2.3, S3.1, S3.2, S3.3, S4.1, S4.2, S4.3, S5.1, S5.2, S5.3, S6.1, S6.2, S6.3, S7.2, S7.3, S8.1, S8.2, S8.3, S9.1, S9.2),

— *may also be useful in the industrial design studio courses whose project subjects are to design small products* (I1, S3.3, S5.3, S8.3, S9.1),

— *will not be useful in the industrial design studio courses whose project subjects are to design small products* (I2, I3, S1.1, S1.2, S1.3, S2.1, S2.2, S2.3, S3.1, S3.2, S4.3, S5.1, S5.2, S6.1, S6.2, S6.3, S7.2, S8.1, S8.2, S9.2).

In terms of "Sustainable Use of VR in Industrial Design Education":

VR technology

— *requires installation/setup* (I1, I2, I3, S1.1, S1.2, S1.3, S2.1, S2.2, S2.3, S3.1, S7.2, S7.3, S8.2, S10.1, S10.2),

— *requires learning* (I1, I2, I3, S7.1, S7.2, S9.1, S10.1, S10.2),

— *requires operating* (I2, I3, S9.2).

VR equipment

— *requires maintenance* (I3, S9.1).

For the use of VR in industrial design education to be sustainable

— *it should be easily accessible and usable for both students and instructors in a studio environment* (I1, I2, S9.1, S9.2),

— *it should be made available with a permanent installation in a studio environment* (I3, S2.1, S2.2, S2.3, S4.1, S4.3, S5.2, S8.2),

— *it should be led/manage by at least one instructor/executive* (I1, S6.3),

— *at least one technical person/expert/operator should meet the requirements of VR technology and equipment* (I2, I3, S2.2, S2.3, S4.1, S8.3, S9.1, S9.2, S10.2).

As a result, the analysis of the questionnaire items and the transcriptions of interview records show that although most of the participants,

— find VR technology useful in various aspects and easy to use at various degrees,

— find using it fun/ enjoyable/ entertaining, and

— tend to recommend it to their friends or colleagues for using it in industrial design studio courses,

there are still some reservations in their minds regarding frequent or continuous use of VR technology in industrial design studio courses. The responses to the scale items FC1 and FC4 indicate two of these reservations:

— The thought of not having enough knowledge (experience) necessary to use it, and

— The thought of not having enough resources necessary to use it.

Another reservation derived from the content analysis results is,

— The thought that the use of it for evaluating designs of small products will not be as useful as the use of it for evaluating designs that are so big that we can get in.

Besides, for the use of VR technology in industrial design education to be sustainable, it is thought that

— it should be easily accessible and usable for both students and instructors with a permanent installation in the studio environment,

— it should be led/managed by at least one instructor/executive,

— the requirements of the technology such as installation/setup, learning, operating, and maintenance requirements should be met by at least one technical person/expert/operator.

5.3.4 Reasons why VR technology was not used in other practices and activities where students and instructors got involved together

Throughout the project process, it was observed that

— only students used VR either individually or together with their group members for evaluating their design decisions and being prepared for the final jury presentation.

— neither students nor instructors demanded or intended to use VR for critiquing the design decisions together.

This situation was questioned in the interviews by asking them why they did not use VR in the studio critique sessions or other activities during the project process.

According to the content analysis results of the interview transcriptions, VR was not used because

- *the VR setup had not been installed in the studio while they were performing the activities to imagine and apprehend the borders of an existing minibus* (S4.3, S6.3),
- *they perceived VR at the beginning as a technology that would only enable them to evaluate and/or present the whole of a design over a finished model* (I1, I2, I3, S1.2, S2.2, S3.1, S4.1, S5.1, S5.3, S6.1, S6.3, S7.2, S8.1, S9.1, S9.2, S10.2). *However, they were critiquing the parts – not the whole – of their designs in the studio critique sessions* (I1, I2, I3, S1.1, S1.2, S3.2, S4.1, S4.2, S5.1, S5.3, S6.1, S6.3, S7.1, S7.3, S8.1, S8.2, S8.3, S9.1, S9.2). (I1: *"...a critique process was not such an evaluation process, and it was a guiding process on how students could think about something not finished yet."*)
- *they were not used to using VR yet* (I1, S1.1, S1.3, S3.1, S8.2, S10.1),
- *they had not yet known and/or been aware of what they could do with VR technology* (I1, I2, I3, S2.2, S5.2, S10.2),
- *no one led and/or directed and/or demanded them to use VR for this purpose* (I2, I3, S2.2, S5.3).
- *using VR for that purpose did not cross their minds then* (I2, I3, S1.1, S1.2, S2.2, S3.1, S3.2).

These results indicate that they did not attempt to use VR technology because they did not yet have sufficient familiarity with and mastery in its use in such activities and practices. Other reasons are (i) its setup not being ready for use when needed; and (ii) perceiving VR as a technology that will only enable to evaluate and/or to present the whole – not the parts – of a design over a finished model.

5.4 Summary

The data collection and analysis processes of this research were carried out in three main stages:

1. First Stage: Initial Investigations (before the in-studio study)
2. Second Stage: Integration of Virtual Reality (in-studio study)
3. Third Stage: Final Investigations (after the in-studio study)

In the first stage, a systematic literature review on related works and a preliminary study with potential users (industrial design students and instructors) were carried out.

The systematic literature review aimed at revealing what the former studies on the use of VR in the professional and educational practices of industrial design say. For this purpose, the papers

- published in English,
- indexed up to 2018 in the databases of Scopus and Web of Science collections,
- involved the phrases “industrial design” and “virtual reality” in their titles, abstracts, or keywords

were reviewed.

The preliminary study aimed at revealing what potential users think about using VR technology in industrial design studio courses. For this purpose, 12 instructors and 26 students participated in the study from 10 universities were introduced to the technology, and then their opinions were taken both quantitively and qualitatively by the questionnaire and group discussion methods. The quantitative data collected by the questionnaire were analyzed using the descriptive statistics methodology, whereas the qualitative data were analyzed using the content analysis method.

The findings of these two investigations showed that

1. VR technology can be used as
    - an inspirational material before the creation of design representations,
    - a sketching, modelling, prototyping and visualization tool in creating design representations,
    - a presentation, demonstration, experiencing, usability evaluation and ergonomic evaluation tool after the creation of design representations,
    - a collaboration tool in and after the creation of design representations

in the industrial design process. However, none of these types of use was tried before to employ under the real conditions of the educational setting of an industrial design studio course.

2. Potential users are eager to use VR technology. However, they have reservations as well as their positive opinions about using it in industrial design studio courses.

   Positively, they consider VR technology as a technology with benefits such as

   — enabling one to experience the designs that are so big that making their prototypes and models is too hard or impossible,

   — decreasing the need for model making or prototyping,

   — facilitating finding mistakes,

   — helping design verification,

   — improving students' 3D perception,

   — increasing students' performance.

   Yet, they think that it will be most useful for the presentation and evaluation of designs because it is thought that it will facilitate design communication.

   On the other hand, the reservations below were expressed:

   — It will not be useful when designing small products. It will only be useful when designing products that are so big that we can get in because it does not provide ergonomic evaluation,

   — Because it is a CAD-based technology, it cannot be employed in the early stages of the design process but can be used effectively after the concept development phase,

   — It is not an easy-to-use technology because it is a complex system in itself and requires learning,

   — It consumes time because it requires too many steps to be taken to experience the design,

   — Studio environments may not be suitable for the VR experience because it requires a large space to experience the design,

— It does not provide an educational environment in which an instructor and a student come together and meet because it does not allow the face-to-face communication between instructors and students,

— It can cause disruptions/interruptions in the course of the lesson because

  - it requires someone to keep an eye on the user while using it
  - it may not be compatible with all computer configurations,
  - it may not be compatible with CAD software used by students,
  - it may not be suitable for instructors and students with vision defects,
  - it may not be suitable for instructors and students wearing glasses,
  - it may cause simulator sickness,
  - it may not be hygienic for multiple users.

— All in all, in terms of educational use, VR technology was considered as a technology that is difficult to adapt to education for schools with a large number of students and evaluated as it could not be used effectively in industrial design studio courses.

Because the results of the preliminary study revealed that potential users think that VR technology will be most useful for presenting and evaluating designs compared to other types of its use, the jury practices of industrial design education where students present their design ideas with their representations and instructors evaluate them were determined as the key practices into which VR technology can be tried to be integrated. Therefore, it was decided,

— to try to integrate VR technology into the jury practices of an industrial design studio course by making the use of it by students mandatory in these practices, and

— to question other types of its use by making it available for use during the studio hours of that course, and then, by observing the voluntary use of it for other studio-based practices.

Additionally, to eliminate or to minimize the reservations revealed as much as possible, it was also decided;

— to carry out the in-studio study in the 3rd year industrial design studio course "EUT 320E Industrial Product Design III" with the project issue "Smart Electric Minibus Design for Anadolu Isuzu",

— to conduct the project process of the course as a group project,

— to make the use of VR technology mandatory in the jury sessions after the concept selection phase,

— to use SimLab Composer 8.0 as the intermediary software to enable experiencing the CAD models in VR scenes,

— to use the HTC Vive VR headset as the VR equipment

— that, during the project process, the researcher would work both: as an operator who is responsible for installing and running the VR system properly, and also responsible for its being used easily and hygienically; and as an educator who will meet the learning need for VR technology.

The second stage was the action research stage that was conducted by intervening in the project process of an industrial design studio course as shown in Figure 5.78. In this stage, it was attempted three times to integrate VR technology into the jury practices of the course. All attempts were observed and recorded with two cameras and a voice recorder, and after each attempt, interviews were conducted with jurors and students, and their opinions were taken. The first attempt was conducted by planning based on the literature, whereas the second and third attempts were carried out by planning based on the findings obtained in the previous attempt.

In all attempts, it was asked students to submit the VR scenes of their design proposals as well in addition to other representations of them before the jury session. For this reason, the VR equipment and software to be used within this research were introduced and taught to students by the researcher in a lesson at the beginning of the course schedule with a three-hour presentation and demonstration.

In the first attempt, an HTC Vive VR headset was tried to be used with a room-scale setup. The HTC Vive VR installation was set up so that its VR experience area was located between the presentation board and the jury table, and it was proposed and anticipated that;

1. Students will explain their design details and decisions behind them by referring to the representations of the designed product such as its drawings and renderings on their design sheets, and its physical model(s).
2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information, if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets and/or (a) physical model(s), jurors can experience the design individually by using the VR headset for better understanding and evaluation.

However, although the use of VR technology as a supporting design representation tool was over-accepted by the students and the use of it as a supporting design evaluation tool was accepted by the jurors, this proposed way of use was not accepted. For the next attempt, jurors demanded

— to use the VR glasses by sitting in their chairs,

— to be able to experience the VR scenes simultaneously with the others and/or whenever they want,

— to be able to contribute to the jury discussion by commenting and showing the things in the VR environment,

— to be able to comfortably and clearly see what a person sees while s/he is experiencing a VR scene,

— not to disrupt the jury process while using VR, and

— the areas reserved for the VR experience and presentations to be separate from each other to be able to experience the VR scenes in comfort and safe,

whereas students demanded

— to be able to comfortably and clearly see what a juror sees while s/he is experiencing a VR scene,

— not to be distracted by the VR use of the jurors or others while presenting their design proposals, and

— to be able to show and explain the things in their VR scenes.

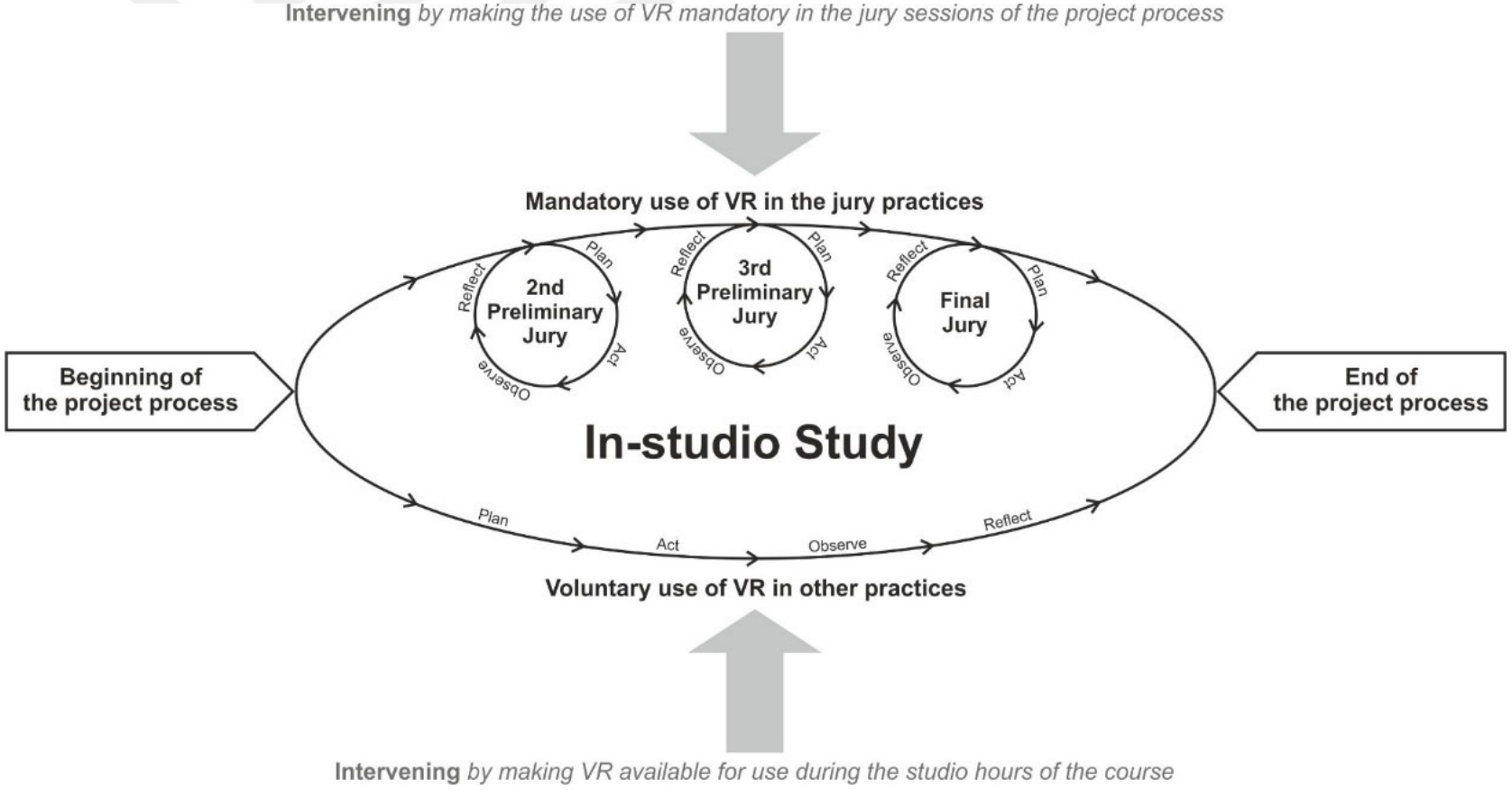


Figure 5.78 : The schematic representation of the second stage.

In the second attempt, by taking these demands into consideration, both an HTC Vive VR headset and VR Box mobile VR glasses were tried to be used. The HTC Vive VR installation was set so that its VR experience area was separate from the area reserved for students' presentations, the VR screen of the HTC Vive headset was projected onto the wall in front of the jurors, and the VR Box mobile VR glasses were left on the table of the jurors for their use. Additionally, it was proposed and anticipated that,

1. Students will explain their design details and decisions behind them by referring to the representations of the designed product, such as its drawings and renderings on their design sheets, and its physical model(s).
2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information, if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets and/or (a) physical model(s),
   - jurors can experience the designs individually by using the VR Box mobile VR glasses or the HTC Vive VR headset for better understanding and evaluation. If they prefer to use the HTC Vive VR headset, they also can contribute to the jury discussion by commenting on and showing the things in the VR environment,
   - students, if they wish, can explain the issues that are misunderstood or not understood by showing the things in their VR scenes with the help of the HTC Vive VR headset.

In this attempt, the jurors never used the HTC Vive installation, however, they actively used VR Box mobile VR glasses. In other words, using VR technology with the help of mobile VR glasses was accepted. On the other hand, only one project group used the HTC Vive installation for explaining their design by showing its representation in their VR scene. This situation revealed that the use of the HTC Vive setup for presentation purposes by students rather than the use of it by jurors for evaluation purposes would be more suitable in terms of the integration of VR technology into the jury practice. On the other hand, the demands that were apart from the use of VR technology in the jury practice began to emerge, such as displaying the digital versions

of design sheets in large size. Accordingly, for the third attempt, the previous proposal for the way of using VR technology in the jury practice was revised as follows:

1. Students will explain their design details and decisions behind them not only by referring to the representations of the designed product such as its drawings and renderings on their digital and non-digital design sheets and its physical model(s) but also by using the HTC Vive headset whose VR screen is projected onto the wall.
2. While the presentation is continuing, jurors may (or not) interrupt it with some comments, or questions for better understanding, or getting further information if there is a missing part regarding the presentation.
3. In this interruption phase or at the end of the presentation, if there are still some issues that could not be clarified or understood by the oral presentation with design sheets, (a) physical model(s), and/or the virtual model in the VR scene
   - jurors can experience the design individually by using the VR Box mobile VR glasses for better understanding and evaluation,
   - students, if they wish, can explain the issues that are misunderstood or not understood by showing the things in their VR scenes with the help of the HTC Vive setup.

In this last attempt, integrating VR technology into the jury practice of industrial design was largely ensured. However, the issue of not being able to see what a juror saw or where s/he looked in a VR scene while experiencing it by using the mobile VR glasses could not be eliminated with the available means.

On the other hand, it was observed that to make VR available for use in the studio environment during the studio hours of the course and give a short training on how to use its hardware and software opened the way of using it as a design evaluation tool by students. Throughout the project process, some of the students and project groups demanded to use VR technology four times in total for evaluating their design decisions on a 1/1 scale and in a realistic way as much as possible – either individually or together with their group members. However, neither students nor instructors demanded or attempted to use VR in other practices and activities where students and instructors got involved together.

In the third stage, a questionnaire-based study and interviews with the user groups were conducted,

- to measure the usability level of the proposed way of VR use in the final jury session,
- to reveal the final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design, and
- to question why VR was not used in other practices and activities where students and instructors got involved together.

The usability level of the proposed way of VR use in the final jury session was measured with the help of System Usability Scale (SUS) items placed in the questionnaire. The SUS score was calculated as 71.3. This score indicates that the usability of the last proposal for using VR technology in the jury practices of industrial design education is "OK" but can be improved. On the other hand, the analysis of the responses to each SUS item separately showed that the thought that using VR in this way requires the support of a technical person and this requirement was the main reason that decreased the SUS score the most.

The final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design were revealed with the help of UTAUT2 and NPS items in the questionnaire and interviewing with the user groups. The analysis of the questionnaire items and interview transcriptions show that although most of the participants,

- find VR technology useful in various aspects and easy to use at various degrees,
- find using it fun/ enjoyable/ entertaining, and
- tend to recommend it to their friends or colleagues for using it in industrial design studio courses,

there are still some reservations in their minds regarding the frequent or the continuous use of VR technology in industrial design studio courses, and these reservations mainly stem from;

— the thought of not having enough knowledge (experience) necessary to use it, and

— the thought of not having enough necessary resources to use it.

— the thought that the use of it for evaluating designs of small products will not be as useful as the use of it for evaluating designs that are so big that we can get in.

Besides, the analysis results also show that participants think that for the use of VR technology in industrial design education to be sustainable,

— it should be easily accessible and usable for both students and instructors with a permanent installation in the studio environment,

— it should be led/managed by at least one instructor/executive,

— the requirements of the technology such as installation/setup, learning, operating, and maintenance requirements should be met by at least one technical person/expert/operator.

The reasons why VR technology was not used in other practices and activities where students and instructors got involved together were questioned with the help of interviews. The content analysis results of the interview transcriptions showed that it was not used because

— the VR setup had not been installed in the studio while they were performing the activities to imagine and to apprehend the borders of an existing minibus,

— they perceived VR at the beginning as a technology that would only enable them to evaluate and/or present the whole of a design over a finished model. However, they were critiquing the parts – not the whole – of their designs in the studio critique sessions,

— they were not used to using VR yet,

— they had not yet known and/or been aware of what they could do with VR technology,

— no one led and/or directed and/or demanded them to use VR for this purpose.

— using VR for that purpose did not cross their minds then.

6. CONCLUSIONS

This chapter presents the conclusions reached throughout and at the end of the research process. The contributions of the study, the limitations of the study, the recommendations for further studies, and a discussion on the methodology and the findings are presented in this chapter as well.

6.1 General Overview and Final Remarks

On the Methodology

In the first stage of the research, two exploratory studies were conducted:

- A systematic literature review on related works
- A preliminary study with potential user groups

The systematic literature review was done by searching papers published only in English and that are also indexed in Scopus and Web of Science. However, the combination of the databases of Scopus and Web of Science refers to a database that covers the papers published in almost all reputable publications in English. But even so, some studies may have been overlooked, but their number and content most probably will not significantly alter the results.

The preliminary study was carried out with 12 instructors and 26 students from 10 universities in Turkey. Although these numbers may be found insufficient in terms of representing the whole universe, considering the qualitative nature of the study and the fact that the number of universities with an industrial design department in Turkey was 26 in total when this preliminary study was conducted, they can be evaluated as sufficient in terms of representing the accessible universe.

On the other hand, although the sample size was relatively small, both qualitative and quantitative data were collected. However, quantitative data was used only for supporting the analysis of qualitative data by depicting the general tendencies and the opinions of the participants.

Another methodological issue in the preliminary study is that two questions asked to the participants in the group discussion session ("What are your positive opinions about using this type of VR technology in industrial design education?" and "What are your negative opinions about using this type of VR technology in industrial design education?") were also added to the questionnaire as open-ended questions. Even though this creates an extra workload in the content analysis process as it requires reducing the numbers of the same responses from the same person to one to avoid counting the same answer twice from the same person, it enabled the researcher to take the opinions of the participants who did not speak in the group discussion session by not preferring to speak or being afraid to speak in front of a community.

In the second stage of the research, an action research was conducted under the real conditions of an industrial design studio course. In this process where the course process and the research process merged, the researcher worked: as one of the instructors of that course; as an operator who is responsible for installing and running the VR system properly, and also, responsible for its being used easily and hygienically; and as an educator who met the learning need for VR. Therefore, this process was a really challenging process for the researcher, especially in terms of three issues:

First, the practices into which the research would be involved, such as jury sessions and studio crits, are the practices that were predetermined and announced in the course schedule and that cannot be repeated if missed. Hence, the researcher had no chance of missing any of these applications – especially the jury sessions. For example, in this process, if the researcher had missed even one of the jury sessions in which VR technology was tried to be used, even if it was due to an illness or another force majeure, the research would have been interrupted. For this reason, conducting such a study with more than one researcher would have been more proper in terms of methodology.

Second, there were approximately 30 days between the jury sessions in which VR technology was tried to be used, and the next attempt (jury session) had to be planned based on the results of the previous attempt (jury session). This meant that in less than 30 days,

1. The face-to-face interviews with 3 instructor-jurors and 28 students have to be conducted,
2. The opinions of 2 invited jury members have to be taken via e-mail,
3. The interview records have to be transcribed, and then they have to be analyzed together with the e-mails from 2 invited jury members,
4. At least 3 hours of video recording from the previous jury session have to be analyzed by watching,
5. The next jury session has to be planned by evaluating all analysis results together, and
6. If extra equipment is required, it has to be provided and made ready for the next session.

The fact that the interviews with the students were conducted as group interviews rather than face-to-face interviews was highly useful in overcoming this time constraint problem.

Third, the observation method was used extensively in this research process. However, it was very difficult for the researcher to make observations due to too much responsibility and workload. Fortunately, recording the jury sessions with two cameras from start to finish and taking as many photos as possible during the processes except for the jury sessions enabled the researcher not to miss some critical issues that he might miss while observing.

In the third stage, two concluding studies were conducted:

— A questionnaire study, and

— Interviews with the user groups

The methodological issue in the questionnaire study is concerned with the graphical representations of responses to the scale items adapted from UTAUT2 (Figure 5.73, Figure 5.74, Figure 5.75, and Figure 5.76). Since this part of the research was conducted only with the instructors and students, the number of participants on behalf of the instructors was three. Although it is obligatory to present the answers of these three instructors separately for some questions, it is not obligatory to present their answers in this way for all questions. However, it is deliberately given in this way to

allow for different readings, although it is known that giving the answers of only three participants in this way is not statistically meaningful.

The last methodological issue is that the interviews with students were conducted as group interviews. Although this methodological choice saved the researcher time in the part related to the use of VR in the jury sessions, it prevented each student from answering each question with the desired saturation. In some group interviews, it was observed that some students gave very long answers to the questions, but other students in the same group sometimes only answered "I agree" to the same question in order not to say the same things one more time, and sometimes they remained silent and nodded their heads to indicate whether they agreed with their friends' opinions or not. However, if they had answered the questions themselves once (even if they repeated what their friends say), some different thoughts that were not in their minds before they began to speak might arise while they were speaking. It should also be noted that this is not a situation that may significantly affect the results because data and method triangulation is employed throughout the research.

On the Findings

In Chapter 3 (3. THEORETICAL FRAMEWORK), it is declared that this research is theoretically framed with

- Design Theory,
- Communication Theory,
- Technology Acceptance Models and Theories, and
- Product Acceptance Models.

Hence, discussing the findings by revisiting the theoretical framework of the study would be better. As mentioned before, within the perspective of Design Theory, designing also includes an effort to show a product that does not yet exist as if it exists. On the other hand, VR technology is a computer-based technology that enables industrial designers to show a product that does not exist yet as if it exists at a high-fidelity level without the need for its physical entity. The findings of this research indicate that this feature is its most important feature in terms of design representation and presentation, and it has the power to change these practices. For example, in the first try to integrate VR technology in the jury practice, it was seen that many students

did not put some details (which were actually expected to be on the design sheets) on their design sheets with the thought that those details can already be seen in their VR scenes. Besides, in the last try to integrate VR technology in the jury practice, it was seen that although one of the 1/10 scale physical models was actively used for presentation purposes and three of them were closely examined by one or two jurors, the 1/10 scale physical models were found "unnecessary" and "useless" by most of the jurors and students. On the other hand, the 1/1 scale physical mock-ups that represent some parts of a design were found "useful". If VR technology becomes one of the widely used (conventional) design representation and presentation tools, perhaps, in the jury practices of industrial design education in the future,

- some details will not be expected to be presented with design sheets and these details will not take place in these sheets, and
- students will not have to make physical models of huge products on 1/1 or any other scale.

Within the perspective of Communication Theory, it can be said that in industrial design education, design representations produced by students not only make design ideas in students' minds visible but also work as agents conveying the reasons behind design decisions to instructors and to peers. Reviewers give feedback to students by looking at and examining these representations. If students use one of the conventional design representation tools, such as design sheets and mock-ups, they can see what a reviewer sees when he looks at the representation and that he gave that feedback by examining which parts of that design (representation). However, VR technology, in its current state, does not offer such an opportunity as default. For this reason, in the attempts for integrating VR technology into the jury practices, students could not see what a juror saw and/or where s/he looked in a VR scene while s/he was experiencing that VR scene by using VR glasses. They were curious about it and wanted to see it to understand how the jurors gave feedback by looking at and experiencing which parts of their designs/virtual representations. On the other hand, it is seen that this desire/curiosity can disappear totally or to a remarkable degree if any verbal feedback about what was seen in the VR scene is given by the juror who experienced that VR scene, or when students show their VR scenes by projecting on a wall with the help of a projector. This situation can be interpreted by making an analogy with the delivery reports offered by Short Message Services (SMS). As known, there are three main

types of delivery reports. The first one reports whether a message has been sent or not. The second one reports whether that message has been delivered or not. The third one reports whether that message has been read or not. In the first step in the jury sessions, students submitted their VR scenes to the researcher. For them, this meant that their messages were sent. In the second step, the jurors wore their VR glasses after the researcher made their VR scenes ready for use. For students, this meant that their messages were delivered. In the third step, if there was any feedback given verbally by the jurors about what was seen in the VR scenes, this feedback meant that students' messages were read. If there was no feedback, there was no delivery report. In the final jury session, students were able to show their VR scenes to the jurors by projecting the VR screen of the HTC Vive VR headset on a wall with the help of a projector. For them, this meant that they read their messages aloud in front of the jurors. Thus, this shortcoming of VR technology was able to be eliminated somewhat. However, it is an important deficiency that can cause interruptions in communication between the jurors/instructors and the students.

Within the perspectives of Technology Acceptance and Product Acceptance Models and Theories, the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) has a better explanation and prediction power compared to other well-known technology acceptance models and theories, and “usability” is the key determinant of a system’s (product's) acceptability. For this reason, the scale items of UTAUT2, SEQ, and SUS in conjunction with interviews were exploited in the relevant parts of this thesis to collect data about the acceptance of using VR technology in industrial design education from participants. The preliminary study results which also include the responses to the scale items of UTAUT2 and SEQ show that almost all the issues raised by potential user groups as problems in terms of integration of VR technology into industrial design education are related to “usability”. However, the results of final investigations which also include the responses to the scale items of UTAUT2 and SUS reveal that these reservations disappeared in the participants who used VR technology in the in-studio study, but reservations related to "facilitating conditions" were emerged. Based on these results and the SUS score which was calculated as 71.3 regarding the proposed way for using VR technology in the jury practice of industrial design education, it can be said that this thesis study has attained its aim. What happens next depends on how willing industrial design educators and

school administrators are to integrate VR into industrial design education, and how much effort they will put into such an integration.

6.2 Conclusions of the Study

People tend to use technology if they believe it will help them do their works better and easier (Davis, 1989). Industrial designers as well have always tended to use computers and computer-based technologies and quickly adopted these technologies. Furthermore, it has usually been observed that these technologies adopted by professionals have been started to be used by industrial design students and/or educators as well and been integrated into industrial design education in some way shortly after their adoptions because it is conducted as a simulation of professional life. However, how the integration of VR technology into industrial design education will occur is still unclear, although it has become economically available for designers with the release of VR headsets such as HTC Vive and Oculus Rift in 2016 and has already been adopted by professionals. Moving from this point of view, this thesis explores how VR technology can be integrated into industrial design education. For this purpose, as presented in Figure 6.1, a study is conducted based on action research methodology. Each part of the research was planned and carried out based on the conclusions of the previous part, and each step taken during this process unveiled information that is valuable for not only guiding the research but also contributing to the literature. Accordingly, this section presents not only the overall conclusion of the study but also the key conclusions reached during the research process.

6.2.1 Key Conclusions of the Study

In the first part of the study, a systematic literature review in addition to the general literature review and a preliminary study with industrial design students and instructors are carried out.

The literature review on the processes in the professional and educational practice of industrial design (2.1 Industrial Design Processes in Practice and Education) indicates that

- industrial design is an iterative process that proceeds through representations, that employs creativity to resolve problems or create solutions, and through

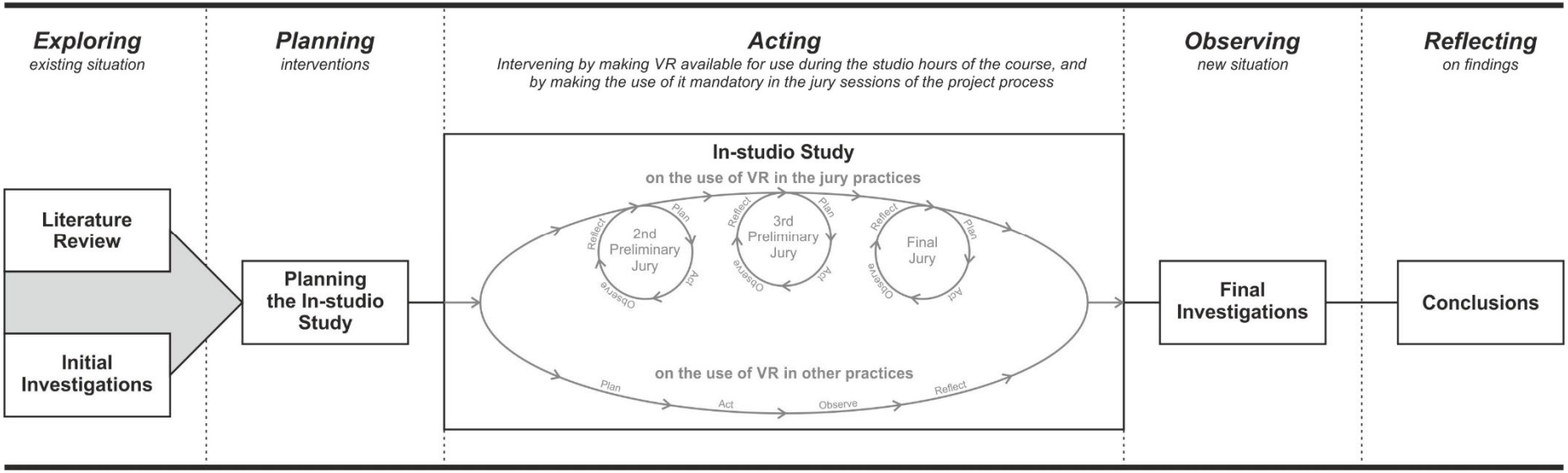


Figure 6.1 : The schematized summary of the research process.

which products, devices, objects, services, and experiences are created, made fit with user needs, and developed (ETMK, n.d.; IDSA, n.d.; WDO, 2015),

— industrial design education is based on the theatrical simulations of the professional practices of industrial design and a studio-based process that proceeds by following workflows and methods used by professional designers to conduct design project processes (Andia, 2002; Laiserin, 2002; Lawson, 2005; Schön, 1985, 1987),

— all designing mechanisms in this process are based on representing design ideas, in other words, making these ideas visible (Goldschmidt et al., 2010; Hough, 2013; Uluoğlu, 2000),

— studio critiques (formal or not) are the main studio-based practices in the educational setting of industrial design studio courses (Hough, 2013),

— representing and presenting design ideas are the core responsibilities of students (Goldschmidt et al., 2010; Hough, 2013; Tovey, 1997),

— giving feedback by evaluating these ideas over their representations is the core duty of instructors (Hough, 2013).

Besides, the literature review on virtual reality (2.2 Virtual Reality) shows that

— VR technology is a computer-based technology that makes showing and/or experiencing a thing that does not exist yet as if it exists possible at a high-fidelity level without the need for any physical entity of it, and

— it can be used for different purposes at all stages of a design process (Coburn, 2017).

In addition, the systematic literature review on the former studies regarding the use of VR technology in practice and education of industrial design (5.1.1 A systematic literature review on related works) reveals that it can be used as

— an inspirational material before the creation of design representations,

— a sketching, modelling, prototyping and visualization tool in creating design representations,

— a presentation, demonstration, experiencing, usability evaluation and ergonomic evaluation tool after the creation of design representations,

— a collaboration tool in and after the creation of design representations

in the industrial design process. However, there are limited number of studies focusing on its use in the educational practice of industrial design, and none of these studies has been conducted by using it in an industrial design studio course under real conditions.

These reviews also show that there is lack of studies in the literature on the use of VR technology in industrial design education.

On the other hand, the preliminary study conducted with 12 instructors and 26 students from 10 universities (5.1.2 Preliminary study) unveils not only the positive and the negative opinions of industrial design students and instructors about the use of it in industrial design education who have not used VR technology for educational purposes before but also their reservations about using it in industrial design education. In this respect, this preliminary study can also be considered as a basis for future studies that can be conducted in similar areas of research as well. Its outcomes put forward that

1. Although potential user groups find VR technology useful in several aspects, they think that it will be most useful in presenting and evaluating designs.
2. Prospective users of VR technology may think that
   — it is a technology that is difficult to adapt to education for schools with a large number of students, and
   — it cannot be used effectively in industrial design studio courses,

   based upon the following thoughts:
   — it will only be useful when designing products that are so big that we can get in because it does not provide ergonomic evaluation,
   — it cannot be employed in the early stages of the design process because it is a CAD-based technology,
   — it is not an easy-to-use technology because it is a complex system in itself and requires learning,
   — it consumes time because it requires too many steps to be taken to experience a design,
   — studio environments may not be suitable for the VR experience because it requires a large space to experience a design,

— it does not provide an educational environment in which an instructor and a student come together and meet because it does not allow the face-to-face communication between instructors and students,

— It can cause disruptions/interruptions in the course of the lesson because

  - it requires someone to keep an eye on the user while using it
  - it may not be compatible with all computer configurations,
  - it may not be compatible with CAD software used by students,
  - it may not be suitable for instructors and students with vision defects,
  - it may not be suitable for instructors and students wearing glasses,
  - it may cause simulator sickness,
  - it may not be hygienic for multiple users.

These results point out that the jury practices of industrial design education, in which students present their design ideas with their representations and instructors evaluate them, are the key practices where VR technology can be integrated into industrial design education. For this reason, in the in-studio study,

1. How VR technology can be integrated into the jury practices of industrial design education was researched by making the use of it mandatory by the students for design representation and presentation purposes and then by trying to use it in the jury sessions of an industrial design studio course, and
2. How VR technology can be integrated into other studio-based practices of industrial design education was researched by making it available for use during the studio hours of that course and observing whether it will be used for/in other studio-based practices.

Although the use of VR technology by students for design representation and presentation purposes in the jury sessions was made mandatory to be able to research how it can be integrated into the jury practices of industrial design education, there was no need to force them to prepare their VR scenes and use them in the jury sessions. Because they were very enthusiastic about using VR technology in the jury sessions and they never lost their enthusiasm till the end of the project process.

Throughout the in-studio study, it was attempted three times to integrate VR technology into the jury practices of the course (5.2.5 Mandatory use of VR in the jury sessions), and in the last attempt, it was able to be integrated into the jury practice of industrial design education. The proposed jury setup layouts in these attempts, the proposed ways for using VR technology in these setups, the VR usage rates in these jury sessions, and the results about the acceptance status of the proposed ways are briefly summarized in Figure 6.2. Each attempt was scrutinized with the observations recorded during the jury sessions and the interviews with the user groups after the jury sessions.

These attempts and examinations show that VR technology can be integrated into the jury practices of industrial design studio courses

- taken by students who know to use CAD software,
- whose project subjects are to design products that are so big that we can get in,
- after the concept selection phase,
- by being met the equipment, software, learning, and operating needs of the technology,

and, to be able to achieve such an integration

1. VR technology should be used by students not only as a design representation tool but also as a design presentation tool.
2. VR technology should be used as an evaluation tool by jurors, and jurors should be able to use this technology without leaving their chairs.
3. The areas reserved for VR experience, VR presentation, and other presentations with conventional methods should not be overlapped. They should be positioned separately as much as possible but not too far from each other.
4. The area reserved for VR experience and/or VR presentation should be large enough for safe use of VR.
5. The way of VR use should not be time-consuming, distracting, and disrupting.
6. All jurors and students should be able to see what someone sees while s/he is experiencing a VR scene.

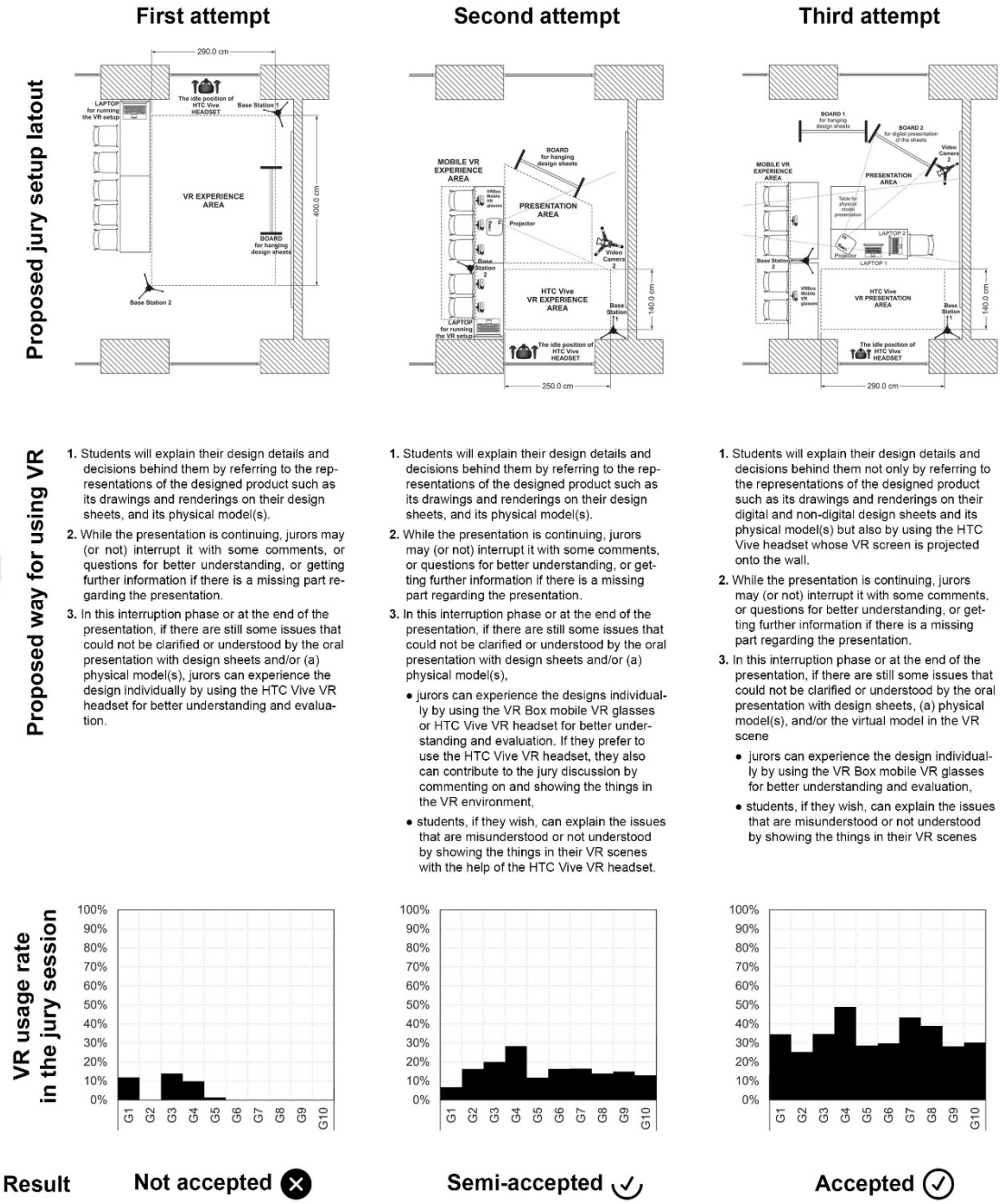


Figure 6.2 : A brief comparison of the attempts in this thesis study to integrate VR technology into the jury practice of industrial design education.

Besides, it should not be overlooked that the jury practice of industrial design education is a system with an established layout and ritualistic phases, and VR technology will be used in this system and as a part of it. Therefore, VR technology should not be used in a way that disrupts its established layout and ritualistic phases.

On the other hand, making VR technology available for use during the studio hours of the course and observing whether it will be used for/in other studio-based practices revealed that

1. Making VR technology accessible in the studio environment and teaching how to use its hardware and software open the way of using it voluntarily as a design evaluation tool by students.
2. Making VR technology accessible in the studio environment and teaching how to use its hardware and software is not enough to start its use in other practices and activities where students and instructors got involved together.

It the last part of the study, final investigations were conducted

- to measure the usability level of the proposed way for using VR technology in the last attempt,
- to reveal the final assessments of students and instructors on the VR technology they used during the project process and its use in the educational practice of industrial design, and
- to question why VR technology was not used in other practices and activities where students and instructors got involved together.

The usability level of the proposed way for using VR technology in the last attempt was measured with the help of the System Usability Scale (SUS) and the SUS score was calculated as 71.3. The analysis of the responses to each SUS item shows that the thought that using VR in this way requires the support of a technical person and this is the main reason why the SUS score decreased. This means that if VR technology becomes available without the need for the support of a technical person, its usability by students and instructors in the jury practices of industrial design education will increase.

The final assessments of students and instructors on the VR technology they used during the project process and on its use in the educational practice of industrial design were revealed with the help of the interviews with students and instructors and the scale items of UTAUT2 and NPS. The analysis of the questionnaire items and the interview transcriptions show that VR technology is evaluated as

- a useful technology in various aspects,
- an easy-to-use technology at various degrees, and
- a fun/ enjoyable/ entertaining technology to use

by most of the actual users. However, they have still some reservations in their minds regarding the frequent or the continuous use of VR technology in industrial design studio courses, based upon the thoughts of/that

- not having enough knowledge (experience) necessary to use it,
- not having enough resources necessary to use it, and
- the use of it for evaluating designs of small products will not be as useful as the use of it for evaluating designs that are so big that we can get in.

And, for the use of VR technology in industrial design education to be sustainable, they think that

- it should be easily accessible and usable for both students and instructors with a permanent installation in the studio environment,
- it should be led/manage by at least one instructor/executive,
- the requirements of the technology such as installation/setup, learning, operating, and maintenance requirements should be met by at least one technical person/expert/operator.

These results indicate that the frequent or the continuous use of VR technology in industrial design studio courses is mainly up to

- providing students and instructors with the necessary knowledge and experience to use this technology,
- providing students and instructors with the necessary resources to use VR technology, and
- the sizes/dimensions of the products to be designed in the project process of industrial design studio courses.

And, the sustainability of the integration of VR technology into industrial design education is mainly up to

- presenting it in a way that students and instructors can easily access and use,
- leading to and managing its use by instructors and administrators, and
- meeting the requirements of the technology such as installation/setup, learning, operating, and maintenance requirements.

Finally, why VR technology was not used in other practices and activities where students and instructors got involved together was questioned with the help of the interviews with students and instructors. In response to this, the following reasons were put forward.

- The VR setup had not been installed in the studio while they were performing the activities to imagine and to apprehend the borders of an existing minibus,
- They perceived VR at the beginning as a technology that would only enable them to evaluate and/or to present the whole of a design over a finished model. However, they were critiquing the parts – not the whole – of their designs in the studio critique sessions,
- They were not used to using VR yet,
- They had not yet known and/or been aware of what they could do with VR technology,
- No one led and/or directed and/or demanded them to use VR for this purpose.
- Using VR for that purpose did not cross their minds then.

These results, as well, support the inference that the use of VR technology in industrial design education depends on

- providing students and instructors with the necessary knowledge and experience to use this technology,
- providing students and instructors with the necessary resources to use VR technology and presenting them in a way that students and instructors can easily access and use,
- leading to and managing its use by instructors and administrators,
- the sizes/dimensions of the products to be designed in the project process of industrial design studio courses.

6.2.2 Overall Conclusion of the Study

This thesis study presents how VR technology can be integrated into industrial design education

- by showing step-by-step how VR technology can be integrated into the jury

practice of industrial design education by developing solutions in line with the needs and demands of students and instructors, and

— by revealing the clues of how it can be integrated into other studio-based practices of industrial design education.

Based on the findings obtained throughout and at the end of the research process, this thesis study states that

1. VR technology can be integrated into the jury practices of industrial design studio courses
   — taken by students who know to use CAD software,
   — whose project subjects are to design products that are so big that we can get in,
   — after the concept selection phase,
   — by being met the equipment, software, learning, and operating needs of the technology.
2. In the context of the integration of VR technology into the jury practice of industrial design education, most of the problems are related to the usability of the technology, and most of these problems can be solved even at the current maturity level of the technology.
3. To be able to use VR technology in an integrated way with the jury practice of industrial design education
   a. It should not be overlooked that the jury practice of industrial design education is a system with an established layout and ritualistic phases, and VR technology will be used in this system and as a part of it. Therefore, VR technology should not be used in a way that disrupts its established layout and ritualistic phases.
   b. VR technology should be used by students not only as a design representation tool but also as a design presentation tool.
   c. VR technology should be used as an evaluation tool by jurors, and also jurors should be able to use this technology without leaving their chairs.

d. The areas reserved for VR experience, VR presentation, and other presentations with conventional methods should not be overlapped. They should be positioned separately as much as possible but not too far from each other.

e. The area reserved for VR experience and/or VR presentation should be large enough for safe use of VR

f. The way of VR use should not be time-consuming, distracting, and disrupting.

g. All jurors and students should be able to see what someone sees while s/he is experiencing a VR scene.

4. In the context of the integration of VR technology into industrial design education, there is one main problem regarding the usefulness of the technology, which is that both potential users and actual users think that VR technology will not be so useful in the design process of small products.
5. For sustainable integration of VR technology into industrial design education,

    a. students and instructors should be provided with the necessary knowledge and experience to use this technology,

    b. students and instructors should be provided with the necessary resources to use it,

    c. it should be presented to students and instructors in a way that it can be easily accessible and usable,

    d. its use should be led and managed by instructors and administrators,

    e. other requirements of the technology such as operating, and maintenance requirements should be met as well.

6.3 Contributions of the Study

This study is one of the first attempts in the literature to integrate VR technology into industrial design education by trying to use it under the real conditions of an industrial design studio course and has made three distinct contributions to the literature.

1. This study outlined what might be the possible attitudes of industrial design students and instructors towards the use of VR technology in industrial design studio courses before and after the actual use of it in those courses.
2. This study shows, step-by-step, one of the ways of integrating VR technology into the jury practice of industrial design education.
3. This study reveals the clues of how it can be integrated into other studio-based practices of industrial design education.

6.4 Limitations of the Study

This study was carried out only with an HTC Vive VR headset and two VR Box mobile VR glasses. Additional devices or technologies such as *KAT WALK* (a kind of omnidirectional treadmill that allows infinite movement in a VR environment by using minimum physical space in the real world) and *LEAP Motion* (a technology that allows natural interaction between users' hands and digital content in a VR environment), which can contribute to the VR experience of students and instructors, could not be utilized in this study.

Besides, the Covid-19 pandemic has made distance education compulsory even in industrial design education for a long time, whose pedagogy is rooted in studio-based education. Online education and hybrid education methods have begun to be widely used in industrial design education. However, this study was conducted before the Covid-19 pandemic. For this reason, it has no output or inference regarding the use of VR technology in online and/or hybrid education of industrial design.

On the other hand, as mentioned before in the section "1.2 Aim and Scope of the Study", this thesis study was carried out in ITU Department of Industrial Design. In other words, this thesis study was conducted within the educational setting and conditions of the ITU Department of Industrial Design. It is known that there are also different education models and pedagogies used for industrial design education in other design schools. Although these models and pedagogies have many similarities, it is also the fact that there are remarkable differences between them. Therefore, once again, it should be underlined that the conclusions of this study should not be generalized to all models and pedagogies of industrial design education.

The methodological limitations of the study have already been presented by discussing in the section “6.1 General Overview and Final Remarks”.

6.5 Recommendations for Further Studies

Although this study shows step-by-step one of the ways to integrate VR technology into jury practice of industrial design education, this study is one of the first attempts in the literature in this respect and has been carried out in a very narrow framework. Hence, its outcomes need to be verified and/or improved with similar studies.

Also, how it can be integrated into other studio-based practices of industrial design education, such as desk crits, is still not clear enough because the relevant part of the study has been conducted with an unstructured intervention. Therefore, there is also a need for further studies to be carried out with structured interventions on this issue.

Besides, two major limitations of this study, mentioned above, also include two recommendations for further studies:

1. It will be useful to explore how devices and technologies that improve the VR experience, such as *KAT WALK* and *LEAP Motion*, can contribute to the integration of VR technology into industrial design education.
2. How VR can be employed in online and hybrid education models of industrial design and how it can contribute to these areas are also subjects in need of research in the literature.

On the other hand, throughout the research process, it has been tried to find out and to resolve the problems regarding the use of VR technology by industrial design students and instructors. It is come up with the result that there are three main issues which underlie most of the problems identified in this process:

1. Being isolated from the real environment.
2. Not being offered a physical-like interaction with virtual design representations by the VR technology used.
3. Not being able to evaluate a virtual design representation together with others at the same time by entering the same VR environment.

These issues, at a first glance, can be considered as the key issues that will define the future of VR use in industrial design practice and education. Because, being isolated

from the real environment means that virtual design representations cannot be evaluated by juxtaposing them with surroundings in the real environment. Being isolated from the real environment also means that users cannot see their hands or other body parts in the VR environment, and they cannot evaluate virtual design representations by juxtaposing them with their hands or other body parts. Besides, the lack of physical-like interaction with virtual objects in the VR environment means that it is not possible to make an ergonomic evaluation by interacting with virtual design representations in a way as in real life. Furthermore, the inability to simultaneously evaluate a virtual design representation together with other instructors or students (or peers or colleagues) by entering the same VR environment is another important factor that hinders the design evaluation process.

However, solutions for these three problems have already been developed technologically to various extents. For example, the new generation of VR headsets is not only VR headsets but also AR headsets. In this way, it has become quite easy to use VR and AR features by switching between VR and AR modes in these headsets. In other words, users can now use this technology either being isolated from the real environment or not. Moreover, these systems are both wireless systems and use inside-out tracking technology. So, there is also no need for any hardware installation in the physical space anymore. On the other hand, Intel has recently introduced a new technology where users can interact with objects in the virtual environment with their hands without any intermediary apparatus such as VR controllers: Project Alloy. This project is one of the first attempts to solve the problem regarding the lack of physical-like interaction with virtual objects in the VR environment. Besides, Autodesk, in its VR Center of Excellence in Munich, offers its corporate customers services that allow multiple users to simultaneously enter the same VR environment and evaluate designs together.

So, the issues mentioned above are only the constraints of this study and will not be the constraints of tomorrow. The actual issues that will determine the future of VR use in industrial design education and profession are: To what extent it will be economically accessible? To what extent it will be mobile? To what extent it will be easy to use? To what extent it will be engaged in related industries? And, for what other purposes will VR be used?

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APPENDICES

APPENDIX A: Additional Tables and Figures
APPENDIX B: Full Versions of On-line Questionnaires
APPENDIX C: Documents handed out to students during the in-studio study
APPENDIX D: Ethics Committee Approvals
APPENDIX E: Additional Supportive Documents
APPENDIX F: Excerpts from the Interviews

APPENDIX A: Additional Tables and Figures

Table A.1 : Creative process models, taken from (Howard et al., 2008, p. 165).

Models	Analysis phase				Generation phase			Evaluation phase	Communication / implementation phase		
Helmholtz (1826)	Saturation				Incubation	Illumination		X	X		
Dewey (1910)	A felt difficulty	Definition and location of difficulty			Develop some possible solutions			Implications of solutions through reasoning	Experience collaboration of conjectural solution		
Wallas (1926)	Preparation				Incubation	Illumination		Verification	X		
Kris (1952)	X				Inspiration			Elaboration	Communication		
Polya (1957)	Understanding the problem	Devising a plan			Carrying out the plan			Looking Back	X		
Guilford (1957)	X				Divergence			Convergence	X		
Buhl (1960)	Recognition	Definition	Preparation	Analysis	Synthesis			Evaluation	Presentation		
Osborn (1963)	Fact-finding				Idea-finding			Solution-finding	X		
Parnes (1967)	Problem, challenge, opportunity	Fact-finding	Problem-finding		Idea-finding			Solution-finding	Acceptance-finding	Action	
Jones (1970)	Divergent				Transformation			Convergent	X		
	Search for data	Understand the problem			Pattern finding	Flashes of insight		Judgement			
Stein (1974)	X				Hypothesis formulation			Hypothesis testing	Communication of results		
Parnes (1981)	Mess finding	Fact-finding	Problem-finding		Idea-finding			Solution-finding	Acceptance-finding		
Amabile (1983)	Problem or task presentation	Preparation			Response generation			Response validation	Outcome		
Barron & Harrington (1981)	X				Conception	Gestation	Parturition	X	Bring up the baby		
Isaksen et al. (1994)	Constructing opportunities	Exploring data	Framing problem		Generating ideas			Developing solutions	Building acceptance	Appraising tasks	Designing process
Couger et al. (1993)	Opportunity, delineation, problem definition	Compiling information			Generating ideas			Evaluating, prioritising ideas	Developing an implementation plan		

Table A.1 (continued) : Creative process models, taken from (Howard et al., 2008, p. 165).

Models	Analysis phase			Generation phase		Evaluation phase	Communication / implementation phase		
Shneiderman (2000)	Collect			Create / Relate			Donate (communicate)		
Basadur et al. (2000)	Problem finding	Fact finding	Problem defn.	Idea finding		Evaluate and select	Plan	Acceptance	Action
	Diverge – converge at each stage								
Kryssanov et al. (2001)	Functional requirements	Structural requirements		Functional solutions	Analogies, metaphors	Reinterpretation	X		

Table A.2 : Details about 2D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
Idea sketch	thumbnail sketch; memo sketch; napkin sketch (Baskinger, 2008; Moyer, 2007; Olofsson & Sjölén, 2007; Pavel, 2005)	basic shapes with simple labels and arrows showing the relationships (Moyer, 2007)	for externalization, visualization, exploration and self-development of ideas; to record and show how the design looks as a physical object (Pei, 2009; Raudebaugh & Newcomer, 1999; Shimizu et al., 1991)
Study sketch	thinking sketch; investigative sketch (Ferguson, 1992; Olofsson & Sjölén, 2007; D. G. Ullman et al., 1990; Van der Lugt, 2005)	few design elements (Lawson, 2005)	to assist the designer to focus and guide thoughts about the design; for investigating the appearance and visual impact of ideas such as aspects of geometric proportion, configuration, scale, layout and mechanism (Ferguson, 1992; Pei, 2009)
Referential sketch	storing sketch (D. G. Ullman et al., 1990)	visual references of observations and insights (Olofsson & Sjölén, 2007)	to record observations and insights; to capture visual references (Graves, 1977; Olofsson & Sjölén, 2007; Pei, 2009)
Memory sketch	–	notes and text annotations (Pei, 2009)	to keep a record of the thoughts and steps taken; to capture and retain thoughts and information for making them easily accessible for further development; for helping remind thoughts and elements from previous work (Do et al., 2000; Pei, 2009; Van der Lugt, 2005)
Coded sketch	–	symbols illustrating a principle (Tjalve et al., 1979a)	to show an underlying principle or a scheme by categorizing information (Pei, 2009)
Information sketch	explanatory sketch; communication sketch; pitching sketch; talking sketch (Eissen & Steur, 2008; Ferguson, 1992; Pavel, 2005; Raudebaugh & Newcomer, 1999)	explanatory information in a graphical setting (Pei, 2009)	to explain the form, function and structure of a concept to stakeholders and clients for evaluation; to stimulate discussion and a common understanding of the design idea among the team (Ferguson, 1992; Van der Lugt, 2005)
Renderings	first concept; sketch rendering (M. A. Evans, 2002; Powell & Monahan, 1987)	perspective views created with the applications of color and tone (Pei, 2009)	to show formal proposals of design concepts; to express the design as realistically as possible (Pei, 2009)
Inspiration Sketch	visionary drawing; emotional sketch (Lawson, 2005; Ling, 2006)	form-oriented visuals of the design concept (Pei, 2009)	to convey the feel of the product; to illustrate the design concept in detail; to influence the audience and to sell the idea (Pei, 2009)

Table A.2 (continued) : Details about 2D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
Prescriptive Sketch	specification sketch (Pavel, 2005)	general arrangement drawings in detail with key dimensions (Pipes, 2007)	to show key dimensions in a freehand orthographic projection with three views drawn to scale; for checking details in preparation for the physical or CAD model (Bertoline, 2002; Pavel, 2005; Pei, 2009)
Concept Drawing	layout drawing (DTI, 1992)	design proposals in color with orthographic views and precise lines (Pei, 2009)	to define the form of the product; to show how the finished product would appear in an orthographic view; to evaluate possible proposals in internal discussions (DTI, 1992; Pei, 2009; Tovey, 1989)
Presentation Drawing	–	a single workable design to be carried forward to the next phase to work out the fine details (Pei, 2009)	to sell the idea and inspire confidence to the client and external stakeholders about concepts (Buxton, 2007; Powell, 1990)
Scenario & Storyboards	–	a timeline describing stages of the use of the product (Pavel, 2005)	to explain the concept in the settings of the user, product or environment; to suggest user and product interaction; to portray the product's use in the context of artefacts, people (Pei, 2009)
Diagram	diagrammatic drawing; schematic drawing (Tovey, 1989)	simple geometric elements and hatching to illustrate the principle or operation of the system (Do et al., 2000)	to group data visually so that the information can be clearly understood; to record functional structures of the product; to show the underlying principle of an idea; to represent relationships between objects (Blackwell, 1997; Pei, 2009; Tjalve et al., 1979b)
Single-View Drawing	–	an axonometric projection made up of either isometric, trimetric, diametric, oblique or perspective view (Bertoline, 2002; Lueptow, 2000)	to examine the geometry; to show alternative arrangements (Do et al., 2000)
Multi-View Drawing	orthographic projection (Bertoline, 2002; Raudebaugh & Newcomer, 1999)	a first-angle or third-angle projection (Pei, 2009)	to describe the features and geometry of a product through three coordinated orthogonal planes made up of plan view, front elevation and end elevation (Bertoline, 2002; Pei, 2009; Raudebaugh & Newcomer, 1999)

Table A.2 (continued) : Details about 2D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
General Arrangement Drawing	model making drawing (DTI, 1992)	a multi-view drawing with dimensions, parts list, sub-assemblies, drawing angles and break lines (DTI, 1992; Martin, 1989)	to represent an overview of the design and how the parts are put together; for discussions with non-technical members; for creating appearance models (Pei, 2009; Powell, 1990)
Technical Drawing	documentation drawing; production drawing; working drawing (Bertoline, 2002; Raudebaugh & Newcomer, 1999)	formalized, complete and standardized multi-view drawings with dimensions, material specifications, parts list, manufacture, finish and assembly details (Pei, 2009)	to cover every detail for manufacture by defining, specifying and graphically representing the built object; to show the material specification, parts list, manufacture, finish and assembly details; for organizing and calculating the production costs (Pei, 2009; Tjalve et al., 1979b)
Technical Illustration	–	section, cut-away, ghosted, and exploded views (Pei, 2009)	to simplify the engineering details and highlight key features without omitting important information; to explain the engineering aspects rather than to communicate the aesthetics; for instruction manuals, installation guides, maintenance manuals, catalogs and in advertisements and training books (Bertoline, 2002; Pei, 2009; Pipes, 2007)

Table A.3 : Details about 3D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
3D Sketch Model	sketch model; 3D rough model (Garner, 2006)	physical representation of the general shape of the product made of soft materials such as foam and balsa wood (Pei, 2009)	to explore potential ideas; to obtaining visual feedback; to translate 2D representations into a tangible medium; (M. A. Evans, 2002)
Design Development Model	foam model (M. A. Evans, 2002)	enhanced physical representation of the general shape of the product with its components (Pei, 2009)	to refine shapes; to investigate how components are fixed; to understand the relationships between components, cavities, interfaces, structure and form (Pei, 2009)
Appearance Model	maquette; block model (Baxter, 1995; M. Evans, 1992)	physical realistic representation of the product with the external outlook without any functional features (Baxter, 1995)	to materialize the design into a realistic physical form; for first-time evaluation of stakeholders and clients; to realistically define the visual aspects of the product (Pei, 2009; Powell, 1990)
Functional Concept Model	principle model; principle-proving model (M. Evans, 1992; Garner, 2006)	mechanical-looking representation of the product (Pei, 2009)	to investigate the working parts of the product concerning aspects such as yield and performance (Buur & Andreasen, 1989)
Concept of Operation Model	–	physical representation of the product's operational structure	to show how the product would be operated, controlled or managed; to communicate the understanding of operational strategies and usage procedures relating to the product. (Buur & Andreasen, 1989; Pei, 2009)
Production Concept Model	–	finalized physical representation of the product	to understand, evaluate and prepare the design for production; for the assessment of processes, costs and requirements before committing to manufacture (Buur & Andreasen, 1989; Pei, 2009)
Assembly Concept Model	–	finalized physical representation of the product's parts	to establish and ascertain aspects concerning the assembly of a product; to evaluate the issues relating to costs and investments in equipment; to provide confidence regarding the component relationships in terms of assembly, cost and investment (Buur & Andreasen, 1989; Pei, 2009)

Table A.3 (continued) : Details about 3D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
Service Concept Model	–	demountable representation of the product	to show how the product can be serviced and maintained; to show how a user would install the product, to show how a service technician would be able to disassemble the product for repairs (Buur & Andreasen, 1989; Pei, 2009)
Appearance Prototype	integration prototype (Yang, 2005)	highly detailed full-scale representation of the product with internal parts (Pei, 2009)	to evaluate the final design and the user interface prior to manufacture (M. A. Evans & Campbell, 2003)
Alpha Prototype	first prototype (Veveris, 1994)	highly detailed full-scale representation made of the material and layout that would be used for the actual product (Pei, 2009)	to verify the outlook; to verify the construction of sub-systems with the actual materials, aesthetics, and layout for the actual product; for strength and impact tests (Pei, 2009; Ulrich & Eppinger, 2003)
Beta Prototype	second prototype (Veveris, 1994)	revisited version of the alpha prototype	to review the resolved features of the alpha prototype; to examine how the product would be used in its intended environment; to calculate the final costs; to work out regulatory issues; for assembly trials, production evaluation and performance tests (Pei, 2009)
Pre-Production Prototype	pilot-production prototype; third or final prototype (Ulrich & Eppinger, 2003; Veveris, 1994)	revisited version of the beta prototype	to check the product and its finishing as a whole; to measure the manufacturing capability; to perform production and assembly assessment in small batches (Pei, 2009)
Experimental Prototype	design-of-experiment prototype (Pei, 2009)	mechanically working representation of the product	to investigate, optimize and evaluate the mechanical properties of the product; to ascertain the feasibility of a product's working parts; to obtain feedback on the functional performance; to parameterize the layout or shape of a product by replicating the actual product's physics (Otto & Wood, 2001; Pei, 2009; Ulrich & Eppinger, 2003)
System Prototype	–	holistic functional representation of the product roughly made of off-the-shelf components (Otto & Wood, 2001; Pei, 2009)	to test and assess functional aspects such as mechanism and performance (Pei, 2009)

Table A.3 (continued) : Details about 3D Visual Design Representations, tabulated by taking from (Pei, 2009).

	Also known as	Includes	Uses
Final Hardware Prototype	–	integrated representation of the product made of its final working internal parts as a whole (Otto & Wood, 2001; Pei, 2009)	to assist in the design and evaluation of product fabrication and other assembly issues (Pei, 2009)
Tooling Prototype	–	physical components of the product produced with the actual materials and tooling	to ensure that the pressed steel components or die castings for tooling are correctly made; to minimize errors as incorrect molds and tooling parts (M. Evans, 1992; Pei, 2009)
Off-Tool Prototype	–	physical components of the product produced with the actual materials and tooling (Pei, 2009)	to validate fit and assembly; to check the finishing of parts (M. Evans, 1992; Pei, 2009)

Table A.4 : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usability/UX	Maturity Level	Does not offer	does not offer adequate interaction with the CAD model	Öncelikle tasarım sürecinde kullanımıyla ilgili olarak düşündüğümüzde, hani, üç boyutlu etkileşim kısmının biraz zayıf olduğunu düşünüyorum. Hani, öğrencilerin bire bir modele müdahale edebileceği bir yazılım geliştirildiğinde yani 3 boyutlu modeli anında büyültüp küçültebileceği, [bunu] anında yapabileceği yazılım olduğunda belki daha hızlı bir etkileşim olabilir öğrenciler ile modelleri arasında. Bu şekilde baya bir yavaşlamış oluyor aslında süreç. Tekrar bilgisayar başına geçiyoruz. Küçültüyoruz büyültüyoruz yerini değiştirmemiz gerekiyor mesela. Orada bir yavaşlama oluyor. Nesnelerin sahnedeki yerinin ve boyutunun ayarlanmasının zor. Dediğim gibi o teknoloji geliştiğinde tatbikî kullanılabilirliği de gelişmiş olacak.
Usability/UX	Individual Use	Not quick and practical	is not quick and practical	
Usability/UX	Individual Use	Consumes	consumes time	
Usability/UX	Individual Use	Not easy to use	is not easy to use technology	
Usability/UX	Design Process	Cannot be used	cannot be employed in the early stages of the design process	Tasarım sürecini düşündüğümde böyle konsept geliştirme sürecinde kullanılmasının zor olduğunu düşünüyorum. Daha çok hani konsept geliştirilir, ürün geliştirilir, belli bir noktaya geldikten sonra kullanımı belki daha efektif olabilir.
Usability/UX	Design Process	Can be used	can be used effectively after the concept development phase	
Usefulness	Competency Development	Improves	improves students' 3D perception	Öğrenciler açısından düşündüğümüzde ben faydalı olacağını düşünüyorum. Çünkü öğrencilerin en büyük eksiği 3 boyut algısında sıkıntılar yaşıyoruz yani büyüklük küçüklük. Bazen bir ürün geliştiriyorlar, maketini yapıyorlar bu sefer devasa bir şey çıkıyor, hiç ummadıkları bir şekilde bir modelle geliyorlar. Bunu mu yaptın, bu 1:1 mi diyoruz, inanamıyoruz. Öğrencilerdeki 3 boyut algısını geliştireceğini düşünüyorum. O açıdan belki büyüklük algısı hani 3 boyut algısı açısından faydalı olabileceğini düşünüyorum.
Usefulness	In overall	Useful	is a useful technology	
Usability/UX	Design Process	Can be integrated	can be integrated into the design process	Yani genel olarak bence tasarım sürecine entegre edilebilir.

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usefulness	Performance	Increases	increases students' motivation in industrial design studio courses	Teknolojinin öğrencilerin stüdyo derslerindeki motivasyonu artırabileceğini öngörüyorum.
Usability/UX	Design Process	Cannot be used	cannot be employed in the early stages of the design process	Şimdi benim yani teknolojiye baktığımda özellikle ürünler belli bir aşamaya geldikten sonra onu bire bir ölçekli olarak görmek faydalı yani katılıyorum kesinlikle.
Usability/UX	Design Process	Can be used	can be used effectively after the concept development phase	
Usefulness	Design Representation	Enables	enables us to experience the design on a 1:1 scale	
Usefulness	In overall	Useful	is a useful technology	
Usability/UX	Educational Use	May not be suitable	Studio environments may not be suitable for the VR experience	İlk kafamdaki soru işareti şimdi ders esnasında ben hoca olarak bunu taktığımda öğrenciyle orada garip bir kompozisyon ortaya çıkıyor. Böyle etrafında dolaşmamız gereken ürünler ama sınıf ortamı da buna müsait olmayabilir.
Usability/UX	Individual Use	Isolates	isolates users from the real environment	Yani öğrenciyle etkileşim aslında biraz zayıf. Çünkü izole bir teknoloji yani ben gözüme takıyorum öğrenci gözüne takıyor bu arada tamamen soyutlanmış oluyoruz. Öyle bir kafamda soru işareti var. Ayrıca izole şekilde kullanılması sınıf veya grup eğitimi esnasında uygun olmayabilir.
Usability/UX	Educational Use	Does not allow	does not allow the face to face communication between instructors and students	
Usability/UX	Educational Use	May not be suitable	may not be suitable for group training	
Usefulness	Design Evaluation	Useless	is useless when designing small products	İkinci olarak da sanki küçük ürünlerden ziyade büyük ürünlerde etkisi olabilecek gibi. Veya işte bizi içine alabilecek kapsayacak ölçekteki şeylerde daha faydalı gibi olduğunu düşündüm. Çünkü zaten küçük mesela ben bir şişe getirmiştim buraya deneyimlemek için ama yani o an onu deneyimlemek çok anlamsız geldi bana. Çünkü zaten küçük bir obje.
Usefulness	Design Evaluation	Useful	is useful when designing products that are so big that we can get in	

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usability/UX	Design Evaluation	Does not allow	does not allow to evaluate the design representation by juxtaposing it with surroundings in the real environment	Bir de küçük bir objenin referans şeyi yok mesela ilk biraz önce öğrenci arkadaşlarımızla da konuşuyorduk. Yani bir şişe koyduğumda diyelim ben normalde bir maketi öğrenciyle sınıfta masaya koyduğumda bire bir ölçekte onu başka şeylerle ilişkilendirebiliyorum. Şimdi burada tamamen biz sanal bir ortamın içerisindeyiz ve dolayısıyla ölçek şeyi biraz kayıyor. Yani onunla ilgili bir geliştirme yapılabilir.
Usability/UX	Maturity Level	Not satisfactory	is not a fully satisfactory technology/needs improvements	
Usefulness	Design Representation	Enables	enables us to experience the design on a 1:1 scale before prototyping or model making	Tasarımı prototip veya model öncesinde 1:1 ölçekli olarak deneyimleme imkanı sunması. Yani en azından prototip yapılmadan veya yapılamayacak ölçekteki şeyleri burada çok rahat bir şekilde deneyimleyebiliriz.
Usefulness	Design Representation	Enables	enables us to experience the designs that are so big that making their prototypes and models is too hard or impossible	
Usability/UX	Educational Use	Requires	requires data transfer every time to experience the design	Bir de şöyle bir şey var yani yine benim kafamda bir soru işareti. Şimdi bu bir anlamda eğitimin standardizasyonu demek. Çünkü belli bir program kullanacağız. Öğrenci gelecek modelini aktaracak. Yani burda gördüğüm kadarıyla. Her seferinde veri aktarma gibi bir ihtiyaç var. Yani bunlar ders esnasında aslında sekteye uğratabilecek şeyler. İşte onun malzemelerini koyacak veya bunu evde yapacak olsa bile bir model aktarma tekrar onu bilgisayarda açma gibi başka zamansal açıdan şeyler de çıkabilir.
Usability/UX	Educational Use	Can cause	can cause disruptions/interruptions in the course of the lesson	
Usability/UX	Educational Use	Consumes	consumes time	
Usability/UX	Educational Use	May not be compatible	may not be compatible with CAD software used by students	Veya herkesin aynı programı kullanması gerekebilir. Yani bu da bir soru işareti? Çünkü mesela bizim eğitimimizde Rhino kullanan öğrencimiz de var 3d stüdyo Max kullanan öğrencimiz de var. İşte Keyshot kullanan Vray kullanan. Şimdi bunların hepsini standardize etmek de tasarım açısından ne derece mümkün onu da tam kestiremedim.
Usefulness	Design Development	Enables	enables us to experience material variations on the design representation simultaneously	Eşzamanlı olarak 3 boyutlu modelin malzeme açışından varyasyonlarının türetilebilmesi.

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usefulness	Performance	Increases	increases students' motivation in industrial design studio courses	Ayrıca öğrencilerin proje dersine yönelik motivasyonunu artırabilecek bir teknoloji.
Usability/UX	Individual Use	Tiring	is tiring	Yorucu olduğunu düşünüyorum.
Usability/UX	Educational Use	May not be suitable	may not be suitable for instructors and students wearing glasses	Gözlük takan öğretim üyeleri veya öğrenciler kullanırken sorun yaşayabilir.
Usability/UX	Educational Use	May not be hygienic	may not be hygienic for multiple users	Hijyen de düşünülmesi gereken diğer bir unsur.
Usefulness	In overall	Useful	is a useful technology	Yani ben faydalı olduğunu düşünüyorum genel anlamda.
Usefulness	Design Evaluation	Facilitates	facilitates the evaluation of design details	Küçük ölçekli objeler için şöyle bir şey söyleyebilirim. Tabiki burada biraz zayıf kalıyor gerçekten hani görmek açısından ama detay görmede bir işe yarayabilir diye düşünüyorum. Yani hani çünkü objeye yaklaştığımızda detayları daha rahat görebiliyoruz gibi geldi bana. Çünkü altından bakmak… Bugün öğrenci arkadaş takı askısı getirdi, aslında küçük bir objeydi oldukça. Büyütmek zorunda kaldık bakmak için. Hani o açıdan detay görme açsından yardımcı olabilir diye düşünüyorum.
Usefulness	Design Evaluation	Does not offer	does not offer a physical-like interaction with the design representation	Bir de olumsuz olarak şunu söyleyebilirim. Model yapmanın yerini tutabilir mi o konuda çok emin değilim. Çünkü model yaparken aslında malzemeyle böyle bire bir bir etkileşimimiz oluyor. Yani texture açısından dokunma açısından bir etkileşimimiz oluyor ama burada VR teknolojileri bu konuda biraz eksik kalıyor gibi geldi bana. Tasarımcı ile ürün arasındaki somut bağı biraz yok ediyor gibi hissediyorum.
Usefulness	Competency Development	Decreases	decreases material knowledge	
Usefulness	Competency Development	Destroys	destroys the physical interaction between the designer and the design	
Usefulness	Performance	Increases	increases efficiency in idea generation	Ürün fikri üretmedeki verimliliği arttıracağını düşünüyorum.
Usefulness	Design Evaluation	Enables	enables us to get an insight about dimensions of the design and user-product relationship without model making	Ürünün maketi yapılmadan, boyutları ve insan ile ilişkisi konusunda öğrencinin fikir sahibi olmasına fayda sağlayacağını düşünüyorum.

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usability/UX	Individual Use	Troublesome	is too troublesome	Fazla zahmetli (süreçte yapılması gereken adımlar fazlaca).
Usability/UX	Individual Use	Requires	requires too many steps to be taken to experience the design	
			[*not in the scope of the study*]	Sistem gereklilikleri masraflı.
Usefulness	Design Evaluation	Enables	enables a better and accurately perceiving of the design	Monitörde baktık önce çevirdik filan. Orda hani ben daha önce de renderlarını görmüştüm. Algıladığımı düşünüyordum. Yalnız gerçekten hani VRda görünce formu daha iyi, daha doğrusu ha böyleymiş hissi oldu bende. Yani monitörde ne kadar çevirsek de orda bir takım perspektif hesaplar vs. burada sonuçta insanın kendi beyninin kurguladığı perspektifle görünce yani kesinlikle formu daha iyi belki de daha doğru algıladığımı söyleyebilirim. Çünkü daha önceki algılardan farklı bir şey. Form, 2B ekrana göre daha iyi algılanıyor.
Usefulness	Design Evaluation	Useful	is useful when designing products that are so big that we can get in	VR belki işte içine bizim girdiğimiz şeyler için
Usability/UX	Maturity Level	Not satisfactory	is not a fully satisfactory technology/needs improvements	Teknoloji biraz daha gelişebilir; örneğin piksellerin görünür olması biraz rahatsız edici sayılabilir.
Usability/UX	Educational Use	Does not provide	does not provide an educational environment in which an instructor and a student come together and meet	Ben de Selami hocama katılıyorum. Öğrenciyle etkileşim konusunda. Çünkü eğitimin içinde iki kişinin bir araya geldiği ve görüştüğü bir ortam sanki sağlayamayacakmış gibi duruyor. O yüzden şu haliyle sanki eğitimde verimli bir şekilde kullanılamayacakmış gibi geliyor.
Usability/UX	Educational Use	Cannot be used	cannot be used effectively in industrial design education	
Usability/UX	Maturity Level	Not satisfactory	is not a fully satisfactory technology/needs improvements	
Usefulness	Design Representation	Enables	enables us to experience the design in 3D	Üç boyutlu olarak ürünü deneyimlemek.

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usability/UX	Educational se	Requires	requires a large space to experience the design	Kullanım alanının genişliği (Olumsuz yönü)
Usefulness	Collaboration	Allows	allows to work together remotely	Bizim tarafımızdan baktığımızda teknoloji çok heyecan verici. Bunu açıkça söylemeliyim. Yani özellikle coğrafi sınırlardan bağımsız, uzaktan beraber çalışabilmenin kolaylaşması, yani stüdyo tarafında jürilerin uzaktan kurulabilmesi mesela o fikir bana ilginç geliyor. Etkileşimi artırması oldukça faydalı.
Usefulness	Collaboration	Facilitates	facilitates collaboration	
Usefulness	In overall	Useful	is a useful technology	
Usefulness	Design Evaluation	Useless	is useless when designing small products	Ama sizin dediğinize katılıyorum. Daha büyük ölçekte daha heyecan verici sonuçlar veriyor sanırım. Nesnelerin büyüklüğü daha doğrusu küçük olması bir bariyer yaratabilir gibi geliyor.
Usefulness	Design Evaluation	Useful	is useful when designing products that are so big that we can get in	
Usefulness	Collaboration	Allows	allows to review the design together in a cheaper way	Özellikle oluşturma maliyetleri göz önünde bulundurulursa bire bir ölçek üzerinde hep beraber tahsis yapma yani review verebilme olanakları anlamlı.
Usefulness	In overall	Useful	is a useful technology	Ben öğrenci için aslında yani derslerde faydalı olacağına inanıyorum.
Usefulness	Competency Development	Destroys	destroys students' manual dexterity	Ve katılıyorum tabiki bu tür teknolojiler aslında öğrencinin el becerisini ortadan kaldırıyor.
Usefulness	Design Presentation	Is a tool	is a perfect tool for presentations and demonstrations	Tabi tasarım yapılıyor. Tasarımcı için değil. Mesela ben zihnimde de görebiliyorum tasarladığım şeyi. Aslında daha çok kullanıcı için ve onu sunum için bence bu teknolojiyi daha uygun görüyorum ben. Tanıtım ve sunum için mükemmel.
Usefulness	Design Evaluation	Enables	enables more detailed evaluation of the design	Tasarımınızı daha detaylı inceleme imkanı sağlıyor.
Usability/UX	Individual Use	Isolates	isolates users from the real environment	Sizi gerçek ortamdan kopardığı için yanınızda daima birinin olması gerekiyor.
Usability/UX	Individual Use	Requires	requires someone to keep an eye on the user while using it	

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usefulness	Design Evaluation	Enables	enables us to evaluate the design in its real size	Tasarlanan objeyi gerçek boyutlarında incelemek, kolaylıkla değişiklikler yapıp bunları obje bütünlüğü içerisinde incelemek yararlı olabilir. Görülmeyen ve oturmayan detayları fark etmek daha kolay olabilir.
Usefulness	Design Evaluation	Enables	enables us to evaluate the design dynamically	
Usefulness	Design Evaluation	Facilitates	facilitates finding mistakes	
Usefulness	Design Evaluation	Does not make possible	does not make possible to evaluate the design representation by interacting with it as in real life	Ellerle etkileşimi gözlemleyebilirsek bir insanın o ürünü nasıl kullandığını inceleyebilirsek işimize yarayabileceğini düşündüm. Objeyi tam olarak hayatın içinde, insan etkileşimiyle inceleyememek tasarımı soyutlaştırabilir.
Usefulness	Design Development	Helps	helps material selection	Malzeme tercihi açısından öğrenciler için faydalı.
Usefulness	In overall	Useful	is a useful technology	
			[*not in the scope of the study*]	Ekonomik nedenler.
Usefulness	In overall	Necessity	VR use is a necessity to stay students up to date on technological knowledge	Öğrencilerin yenilikçi teknolojiyle iç içe olması mezuniyetleri sonrası piyasada güncel kalmalarına yardımcı olacaktır bu nedenle gerekli olduğunu düşünüyorum.
Usability/UX	Educational Use	Difficult to adapt	is a technology that is difficult to adapt to education in schools with a large number of students	Yüksek sayıda öğrenci mevcudu olan okullarda bu teknolojinin eğitime adapte edilmesinin zor olduğunu düşünüyorum.
Usefulness	Design Evaluation	Enables	enables us to experience the design in a very realistic way	Ürünü oldukça gerçekçi bir şekilde deneyimleme şansı sunuyor. Tasarım dinamik olarak incelenebiliyor.
Usefulness	Design Evaluation	Enables	enables us to evaluate the design dynamically	

Table A.4 (continued) : Content analysis example (The content analysis of instructors' written and verbal data in the preliminary study).

Theme	Category	Code	Condensed Meaning Unit	Meaning Unit (in Turkish)
Usability/UX	Individual Use	Can cause	can cause difficulty in keeping the body balanced	Vücudumun dengesini sağlamakta güçlük çektim. Duvar ya da herhangi bir engele çarpmamak için fazladan zihinsel çaba harcadım. Ellerimi görebilseydim daha rahat ederdim.
Usability/UX	Individual Use	Requires	requires extra mental effort not to hit a wall or any other obstacle	
Usability/UX	Individual Use	Does not allow	does not allow users to see their hands or other body parts in the VR scene	
Usability/UX	Individual Use	Not comfortable	VR use is not comfortable	
Usability/UX	Maturity Level	Not satisfactory	is not a fully satisfactory technology/needs improvements	Tam anlamıyla tatmin edici olmasa da ürünü deneyimlemek (boyut, form vb.) açısından yararlı ve ürünü geliştirmeye teşvik edeceğini düşünmekteyim.
Usefulness	In overall	Useful	is a useful technology	
Usefulness	Performance	Encourages	encourages to develop the design	
Usefulness	Design Evaluation	Does not provide	does not provide ergonomic evaluation	Ergonomik değerlendirme açısından veri sağlayamaması; El ile oran vb. şekillerde ürünü deneyimlemeyi olanaklı kılmaması.
Usefulness	Design Evaluation	Does not allow	does not allow to evaluate the design representation by juxtaposing it with hands or other body parts	

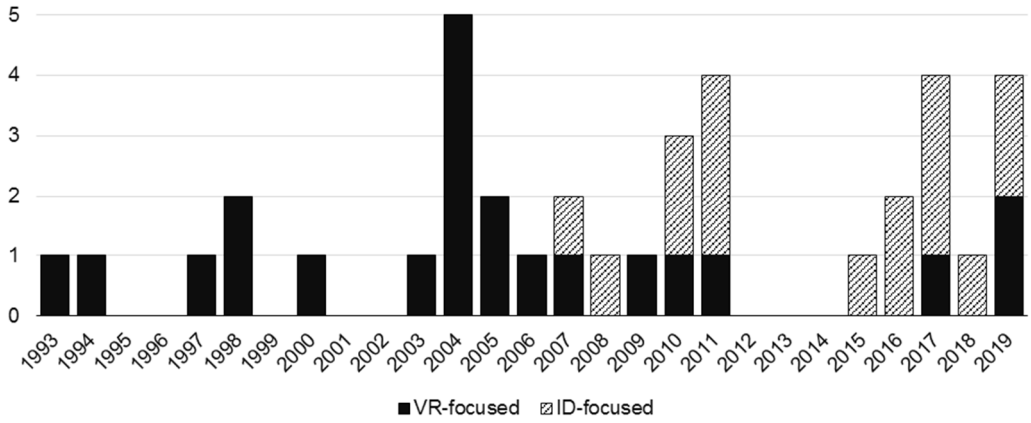


Figure A.1 : The stacked column chart of the selected studies by years, taken from (Hamurcu et al., 2020).

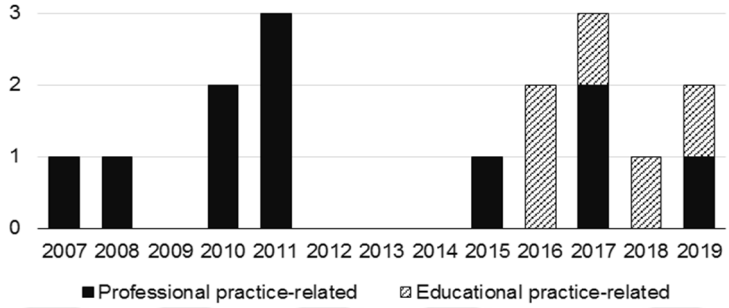


Figure A.2 : The stacked column chart of the ID-focused studies by years, taken from (Hamurcu et al., 2020).

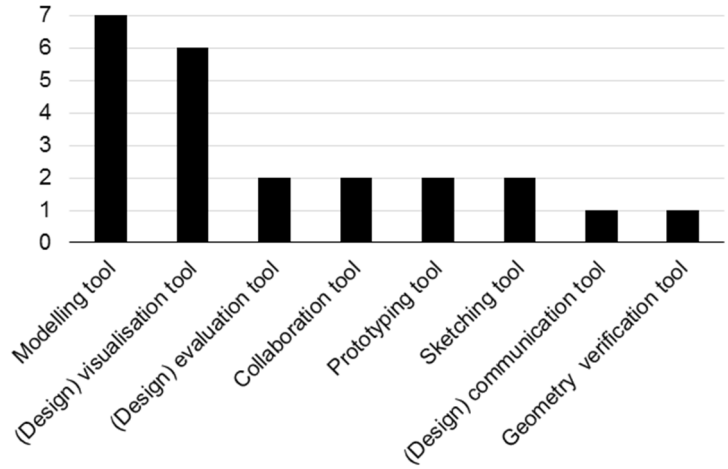


Figure A.3 : Types of handling of VR in VR-focused studies, taken from (Hamurcu et al., 2020).

Table A.5 : VR use types in professional practice-related studies, taken from (Hamurcu et al., 2020).

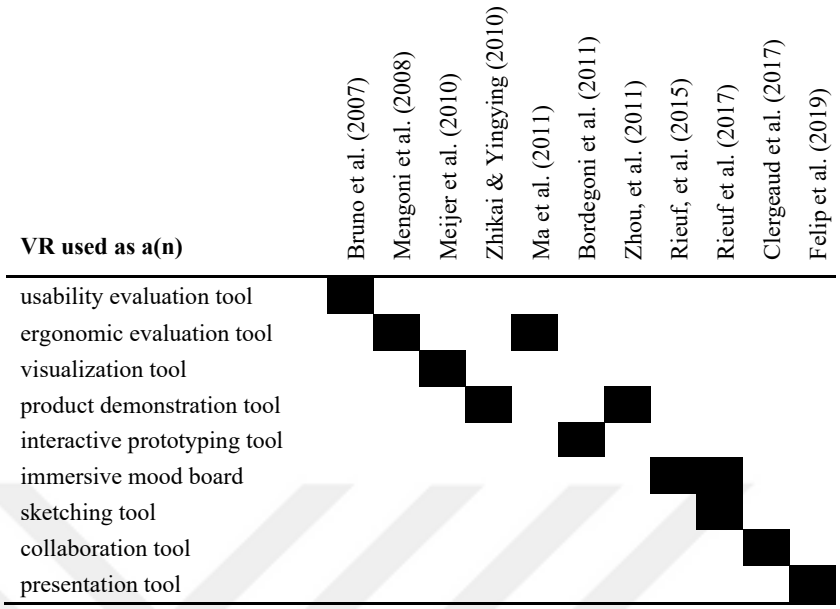


Table A.6 : The studies related to the use of VR in industrial design education, taken from (Hamurcu et al., 2020).

Author(s)	Year	Title	IDE-related Aim(s)
Liang, Y. W., Lee, A.S., Liu, S.F.	2016	A study on design-oriented demands of VR via ZMET-QFD model for industrial design education and students' learning	To analyze and comprehend the ideal design-oriented VR system for industrial design students; to generalize the industrial students' VR demands
Jimeno-Morenilla, A., Sánchez-Romero, J. L., Mora-Mora, H., Coll-Miralles, R.	2016	Using virtual reality for industrial design learning: a methodological proposal	To develop a methodology that enables not only learning different design techniques but also assessing the creativity skills of students in industrial design engineering courses.
Camba, J. D., Soler, J. L., & Contero, M.	2017	Immersive visualization technologies to facilitate multidisciplinary design education	To get students to investigate how immersive 3D visualizations can enrich the delivery of design information; to get them to enhance presentations and simulations in their respective fields
Hamurcu, A.	2018	User Insights about Using Immersive Virtual Reality in Industrial Design Studio Courses	To understand the attitudes of industrial design students and instructors towards using virtual reality technology in industrial design courses
Shih, S. L., Ou, S. J., Huang, Y. C., Mu, Y. C.	2019	The difficulties and countermeasures of applying virtual reality to industrial design education	To explore the effectiveness of using VR as a drawing tool in industrial design education

APPENDIX B: Full Versions of On-line Questionnaires

1. The preliminary study's questionnaire prepared with Google Forms (in Turkish)

VR Deneyimi Değerlendirme Anketi

Bu çalışma İTÜ Endüstri Ürünleri Tasarımı Bölümü'nde doktora yapmakta olan Araş.Gör. Ahmet Hamurcu'nun tez çalışması için bir ön araştırma verisi toplamak amacı ile gerçekleştirilmektedir. Bu anketi doldurmanız, araştırmaya katılmayı ve etkinlikten elde edilecek verilerin akademik bağlamda kullanılmasını kabul ettiğiniz anlamına gelecektir. Bu çalışmadan elde edilecek bilgiler tamamen araştırma amacı ile kullanılacak olup kişisel bilgileriniz gizli tutulacaktır; ancak verileriniz yayın amacı ile kullanılabilir. Eğer bu çalışma hakkında şimdi veya sonra daha fazla bilgiye ihtiyaç duyarsanız araştırmacıya hamurcua@itu.edu.tr e-posta adresi ve 05362241825 numaralı telefondan ulaşabilirsiniz. Ankete devam etmek istemezseniz istediğiniz an çalışmadan çekilebilirsiniz. Çalışmayı yarım bırakmanızın size hiçbir yaptırımı yoktur. Yarım bırakılan anketler çalışmaya dahil edilmeyecektir.

* Gerekli

1. Yaşınız nedir? *

2. Cinsiyetiniz nedir? *

   Yalnızca bir şıkkı işaretleyin.

   - ◯ Kadın
   - ◯ Erkek

3. Eğitim durumunuz nedir? *

   Yalnızca bir şıkkı işaretleyin.

   - ◯ Ön Lisans mezunu
   - ◯ Lisans 1. sınıf öğrencisi
   - ◯ Lisans 2. sınıf öğrencisi
   - ◯ Lisans 3. sınıf öğrencisi
   - ◯ Lisans 4. sınıf öğrencisi
   - ◯ Lisans mezunu
   - ◯ Yüksek Lisans öğrencisi
   - ◯ Yüksek Lisans mezunu
   - ◯ Doktora öğrencisi
   - ◯ Doktora mezunu

4. Şu an bağlı bulunduğunuz üniversitedeki pozisyonunuz nedir? *

   Uygun olanların tümünü işaretleyin.

   - ☐ Öğrenciyim
   - ☐ Akademisyenim (Öğretim Üyesi / Öğretim Görevlisi / Araştırma Görevlisi vb.)
   - ☐ Üniversite Dışından Ders Veren Eğitimciyim

5. Az önceki sanal gerçeklik (VR) deneyiminiz sırasında gözünüze takmış olduğunuz VR gözlüğü ve beraberinde ellerinizle tuttuğunuz kontrol çubukları (HTC VIVE Headset) ile veya bu tarzdaki setler ile daha önceden bir tecrübeniz olmuş muydu? *

   Yalnızca bir şıkkı işaretleyin.

   - ◯ Evet, bu tarz cihazları kullanmaya aşinayım/alışkınım
   - ◯ Evet, ama bu tarz cihazları kullanmaya hakim değilim
   - ◯ Hayır, hiç kullanmadım

6. 3 boyutlu (3D) modeli yazılıma (Vred) aktarmak ve sanal gerçeklik (VR) ortamında deneyimlemek için bazı düzenlemeler yapmak (malzeme oluşturmak ve atamak vs.) bence... *

   Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	6	7	
Çok zordu	◯	◯	◯	◯	◯	◯	◯	Çok kolaydı

7. Sanal gerçeklik (VR) ortamına aktarmış olduğum 3 boyutlu (3D) modeli VR ortamında deneyimlemek bence... *

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	6	7	
Çok zordu	◯	◯	◯	◯	◯	◯	◯	Çok kolaydı

8. 0'dan 10'a kadar bir ölçekte, bu VR teknolojisini endüstriyel tasarım stüdyo derslerinde kullanması için bir arkadaşınıza veya iş arkadaşınıza tavsiye etme olasılığınız nedir? *

Yalnızca bir şıkkı işaretleyin.

	1	2	3	4	5	6	7	8	9	10	
Kesinlikle etmem	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Kesinlikle ederim

9. VR teknolojisinin endüstriyel tasarım stüdyo/proje derslerinde kullanışlı/faydalı olacağını düşünüyorum. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

10. VR teknolojisini kullanmak işleri daha kolay/hızlı halletmemi sağlayacaktır. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

11. VR teknolojisini kullanmak verimliliğimi/üretkenliğimi arttıracaktır. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

12. VR teknolojisini kullanmayı öğrenmek benim için kolay olacaktır. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

13. VR teknolojisi ile etkileşimim açık (clear) ve anlaşılırdı (understandable). *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

14. VR teknolojisinin kullanımının kolay olduğunu düşünüyorum. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

15. VR teknolojisinin kullanmakta ustalaşmamın kolay olacağını düşünüyorum. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

16. VR teknolojisini kullanmanın eğlenceli/keyifli/zevkli olacağını düşünüyorum. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

17. VR teknolojisini kullanmayı sürdürmek niyetindeyim. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

18. VR teknolojisini endüstriyel tasarım stüdyo/proje derslerinde her zaman kullanmaya çalışacağım. *

Her satırda yalnızca bir şıkkı işaretleyin.

	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

19. VR teknolojisini sıklıkla kullanmayı planlıyorum. *

Her satırda yalnızca bir şıkkı işaretleyin.

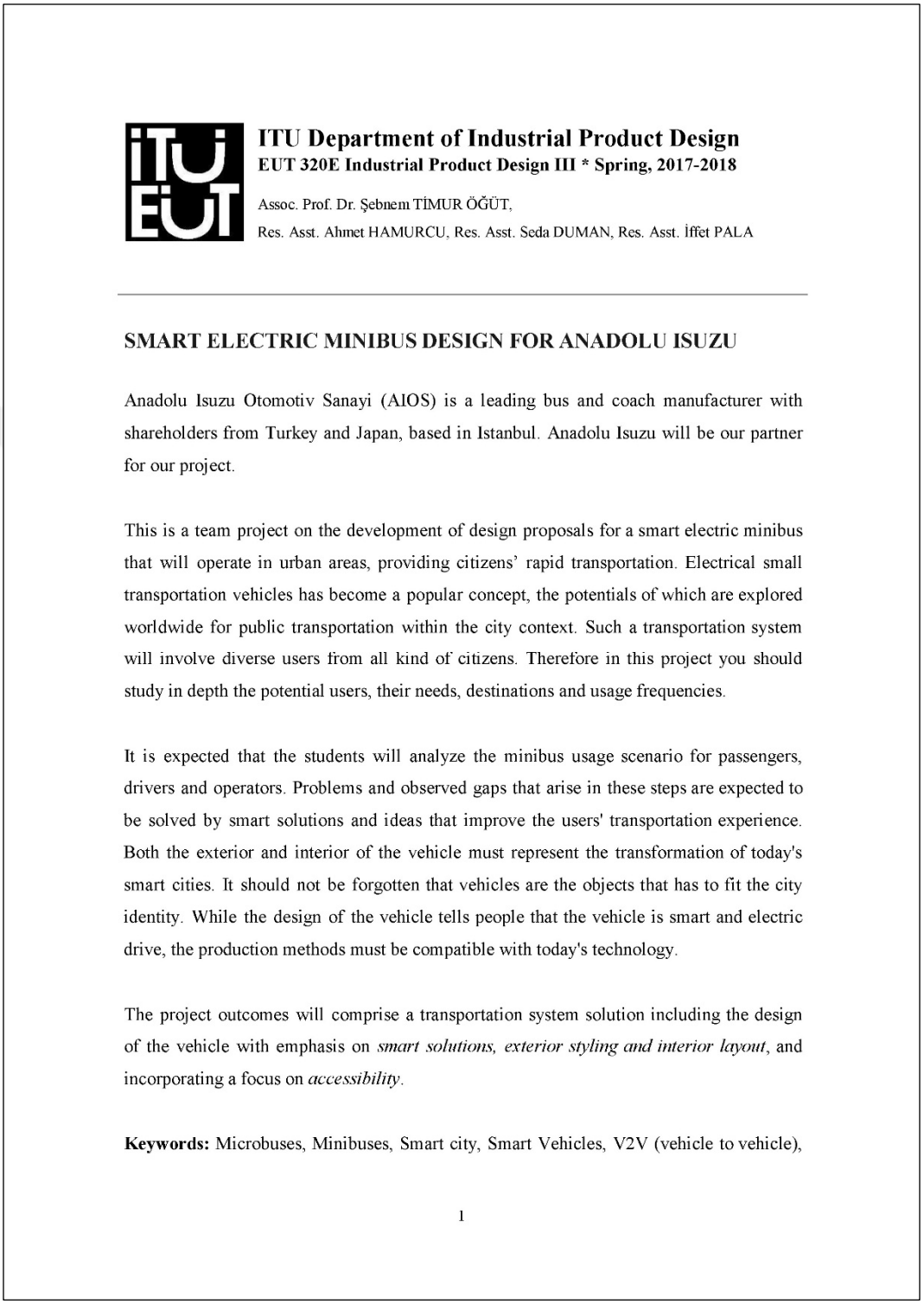
	Kesinlikle katılmıyorum	Katılmıyorum	Bir noktaya kadar katılmıyorum	Kararsızım	Bir noktaya kadar katılıyorum	Katılıyorum	Kesinlikle katılıyorum
Seçiniz	◯	◯	◯	◯	◯	◯	◯

20. Bugün deneyimlemiş olduğunuz VR teknolojisinin endüstriyel tasarım eğitimi bağlamında OLUMLU olduğunu düşündüğünüz yönlerini birkaç cümle ile yazar mısınız?

21. Bugün deneyimlemiş olduğunuz VR teknolojisinin endüstriyel tasarım eğitimi bağlamında OLUMSUZ olduğunu düşündüğünüz yönlerini birkaç cümle ile yazar mısınız?

APPENDIX C: Documents handed out to students during the in-studio study

1. Full text of the Project Brief



ITU Department of Industrial Product Design
EUT 320E Industrial Product Design III * Spring, 2017-2018

Assoc. Prof. Dr. Şebnem TİMUR ÖĞÜT,
Res. Asst. Ahmet HAMURCU, Res. Asst. Seda DUMAN, Res. Asst. İffet PALA

SMART ELECTRIC MINIBUS DESIGN FOR ANADOLU ISUZU

Anadolu Isuzu Otomotiv Sanayi (AIOS) is a leading bus and coach manufacturer with shareholders from Turkey and Japan, based in Istanbul. Anadolu Isuzu will be our partner for our project.

This is a team project on the development of design proposals for a smart electric minibus that will operate in urban areas, providing citizens' rapid transportation. Electrical small transportation vehicles has become a popular concept, the potentials of which are explored worldwide for public transportation within the city context. Such a transportation system will involve diverse users from all kind of citizens. Therefore in this project you should study in depth the potential users, their needs, destinations and usage frequencies.

It is expected that the students will analyze the minibus usage scenario for passengers, drivers and operators. Problems and observed gaps that arise in these steps are expected to be solved by smart solutions and ideas that improve the users' transportation experience. Both the exterior and interior of the vehicle must represent the transformation of today's smart cities. It should not be forgotten that vehicles are the objects that has to fit the city identity. While the design of the vehicle tells people that the vehicle is smart and electric drive, the production methods must be compatible with today's technology.

The project outcomes will comprise a transportation system solution including the design of the vehicle with emphasis on *smart solutions, exterior styling and interior layout*, and incorporating a focus on *accessibility*.

Keywords: Microbuses, Minibuses, Smart city, Smart Vehicles, V2V (vehicle to vehicle),

1

Figure C.1 : Pages of the project brief.

V2X (vehicle to infrastructure), IOT (Internet of things), User experience, Smart Solutions, Innovative, service system, payment system, efficiency; accessibility; design for all; practicality; rapidity; organization; hop on-hop off; intelligent; vehicle identity.

Project Organization Structure

A project team consisting of three students will develop each project. Instructors will announce teammates. Each team will get critiques from each project co-faculty on the announced dates in the studio. On the other hand, each teammate must present his/her own sketches and ideas during studio sessions and will be graded based on his/her personal performance as well as the overall team performance.

Desk Research Topics (due to 13.February.2018 Tuesday)

Groups are assigned one of the topics below. You will make research using print sources, online sources, the literature, and field survey on your assigned topic and prepare powerpoint presentations along with research reports in pdf format that will be uploaded to Ninova.

1. **GROUP -** ISUZU and its local and global competitors in the sector and their related products (e.g. variety, similarities, differences, competitor firms / brands, conveying brand identity through vehicle design and styling, ways in which brands differentiate themselves from others in related vehicles).
2. **GROUP -** Smart city concepts and smart transportation solutions targeting improvement in users experience.
3. **GROUP -** Electrical vehicles, areas of use, the design considerations and necessary infrastructure.
4. **GROUP -** Types of public transportation vehicles, particularly microbuses, minibuses and shuttle-type vehicles, minibus transport solutions around the world.
5. **GROUP -** Materials and production processes for the automotive sector and transport efficiency and implications on vehicle design.
6. **GROUP -** Standards and regulations that should be considered in approaching the design problem (e.g. dimensions, ergonomic considerations, safety regulations, etc.).
7. **GROUP -** Characteristics of the target market; ergonomic considerations for public use transportation layout design.
8. **GROUP -** Current design trends in vehicle design: Features, accessories, components, graphics, colors, and textures.
9. **GROUP -** Automotive design process: Stages and practices (e.g. clay modeling and other specific sketching and modeling techniques).
10. **GROUP -** Conceptual projects about electric powered transportation and similar vehicles; visions for the future.

Figure C.1 (continued) : Pages of the project brief.

User Research Topics (due to 27.February.2018 Tuesday)

For this assignment, we expect teams to go out on site and observe people using public transportation and prepare powerpoint presentations along with research reports in pdf format that will be uploaded to Ninova.

- Observation of users, interviews with users, and self-experience as users.
- Who are the users (the variety in user profiles, motivations, occupations, etc.)?
- What are the daily routines of your users?
- What is their frequency of use of public transportation (daily, weekly, etc.)?
- Are there different types of public transportation that they use?
- What is their route and how many changes do they make?
- How long does their travel take to their destination?
- What are the problems they encounter waiting for, getting on and off, and traveling on the transports?
- What are the advantages they experience, or benefits they gain?
- What are the personal items they travel with, or their work or study related equipment?
- Do they mention any needs for improvement in terms of storage, communication, amount of stops, etc.?

Project Time Table

Week	Date	Studio Content
1	06.02	– Introduction of the project subject – Distribution of the Design Brief on NINOVA – Forming of the project groups – Announcing of the research papers demand as a homework
	09.02	– Confirmation of the groups – Group Research Work
2	13.02	– Technical presentation by ISUZU – **Group Presentations I: Desk Research Findings and Research Reports**
	16.02	– Studio Work
3	20.02	– Studio Work
	23.02	– Studio Work
4	27.02	– **Group Presentations II: User Research Findings and Research Reports**

3

Figure C.1 (continued) : Pages of the project brief.

	02.03	– **Individual Concept Proposals**
5	06.03	– Concept Development
	09.03	– Concept Development
6	13.03	– **Preliminary Jury 1** Concepts proposed by each group member
	16.03	– Design Development
7	20.03	– Design Development
	23.03	– Design Development
8	27.03	**Mid Term Break / No class**
	30.03	**Mid Term Break / No class**
9	03.04	– Design Development
	06.04	– **Preliminary Jury 2** Exterior and interior solutions
10	10.04	– Design Development and Refinement
	13.04	– Design Development and Refinement
11	17.04	– Design Development and Refinement
	20.04	– Design Development and Refinement
12	24.04	– Design Development and Refinement
	27.04	– Design Development and Refinement
13	01.05	**Labor Day / No class**
	04.05	– **Preliminary Jury 3** Final review
14	08.05	– Presentation and Prototyping (Virtual & Physical)
	11.05	– Presentation and Prototyping (Virtual & Physical)
15	15.05	– Presentation and Prototyping (Virtual & Physical)
	18.05	– Presentation and Prototyping (Virtual & Physical)

Expected Outcomes

Each project should be innovative and expected to propose;

- an exterior solution
- an interior solution
- a user experience scenario
- a service and payment system
- an integrated solution within the concept of smart cities

4

Figure C.1 (continued) : Pages of the project brief.

Submission requirements

1. Design Drawings
   The drawings must include:
   - Design concept based on user research
   - Exterior and interior solution
   - User experience scenario
   - Service and payment system
2. Technical Drawings
   Technical drawings must include:
   - Scaled orthographic views with detailed dimensions
   - Sectional views
   - Detail drawings
   - Exploded perspective drawings
3. 3D Virtual Model - (3D print ready) and physical 1/10 scaled model
4. Digital documentation of the project
5. Each student will have a personal journal and keep a blog of their individual and/or group work on a daily basis. The journals will be seen and signed by tutors. This will be used as an evaluation mechanism for individual assessment.
6. A template will be provided for groups to be filled with the required texts and visuals of the projects that will be used as a format ready to be printed as a project booklet.

Digital files of Design Drawings and Technical Drawings must be submitted in pdf format in flash drive during at the project submission stage (maximum resolution for design drawing pdf files must be 300 dpi).

Presentations and submissions throughout the term will be uploaded to Ninova.

Grading

Presentations during the semester		%10
Design Process (attendance, response to studio critics, etc.)		%30
Final Submission	Design concept (Considering smart solutions, exterior styling and interior layout, accessibility)	%15
	Decisions on function, form, material, manufacturability, and pricing, product identity	%15
	Technical details	%10
	3D Virtual & Physical Model	%10
	Presentation quality	%10

__Attendance to class is compulsory__ *Students who will miss the class more than **8 times** throughout the semester will automatically fail the course.*

5

Figure C.1 (continued) : Pages of the project brief.

2. Informed Consent Form

Bilgilendirilmiş Onam Formu

İstanbul Teknik Üniversitesi Mimarlık Fakültesi Endüstri Ürünleri Tasarımı Bölümü araştırma görevlisi Ahmet Hamurcu'nun doktora tezi kapsamında yürütülen ve öğretim üyesi Doç. Dr. Şebnem Timur Öğüt'ün tez danışmanı olarak yer aldığı "Kapsayıcı Sanal Gerçeklik Ortamlarında Kullanıcı Deneyiminin Ölçülmesi ve Tasarlanması" başlıklı araştırmaya katılımınız rica olunmaktadır. Bu çalışmaya katılımınız tamamen gönüllülük esasına dayanmaktadır. Lütfen aşağıdaki bilgileri okuyunuz ve katılmaya karar vermeden önce anlamadığınız her hangi bir şey varsa çekinmeden sorunuz.

ÇALIŞMANIN ADI: **Kapsayıcı Sanal Gerçeklik Ortamlarında Kullanıcı Deneyiminin Ölçülmesi ve Tasarlanması** (Measurement and Design of User Experience in Immersive Virtual Reality Environments)

ÇALIŞMANIN AMACI: Bu çalışma ile yüksek teknolojili kafa setleri (HTC Vive vb.) veya düşük teknolojili gözlükler (Google Cardboard vb.) üzerinden deneyimlenen kapsayıcı sanal gerçeklik teknolojilerinin (Virtual Reality – VR / Augmented Reality – AR / Mixed Reality – MR) endüstriyel tasarım proje dersi sürecinde kritiklerde ve jürilerde tasarım temsil ve sunum araçlarından birisi olarak ilerleyen yıllarda kendine yer bulup bulamayacağının araştırılması amaçlanmaktadır. Bu araştırma kapsamında öğrencilerin ve eğitmenlerin bu süreçte ve sanal gerçeklik ortamında yaşayacakları deneyim ölçülmeye ve mevcut teknolojinin kullanımına aracılık eden yazılım ve ekipmanların tasarım kararları genel olarak kullanılabilirlik ve kullanışlılık kriterleri çerçevesinde sorgulanmaya çalışılacaktır.

PROSEDÜRLER:
Bu çalışmaya gönüllü katılmak istemeniz halinde yürütülecek çalışmalar şöyledir;

1. **Günlük Çalışması**:
   Dönem boyunca tutacağınız günlüklere ilgili teknolojiyi kullanma deneyiminize dair bilgileri de not almanız istenecek ve dönem sonunda sizlerden alınarak analiz edilecektir. Bu analizlerde katılımcıların kimlik bilgileri kesinlikle önemsiz olup sadece ilgili çalışmaya dair veriler incelenecektir.
2. **Gözlem**:
   Dönem boyunca araştırmaya konu olan teknolojinin stüdyo dersi kapsamında kullanımı gözlemlenecek olup yine kişisel bilgilerin önemsiz olduğu bir çalışmadır. Dönem içerisinde gerçekleşecek ara jüriler ile dönem sonundaki final jürisi de gözlemlenecek olup bu jüri oturumlarında görüntü ve ses kaydı da alınacaktır. Bu kayıtlar kesinlikle araştırmacılar haricinde kimse ile paylaşılmayacaktır.
3. **Kullanıcı Testleri:**
   Dönem boyunca 3 kez kullanıcı testi yapılacaktır. Bu testler aracı yazılımlar ve ekipmanları ile teknolojinin kullanılabilirliğini ölçmeye yöneliktir; katılımcıların bilgi ve beceri seviyelerini ölçmeye yönelik değillerdir.
   Bu testler bir kez aracı yazılımın kullanımı ile CAD modelinin sanal gerçeklik ortamına aktarılması, bir kez sanal modelin yüksek teknolojili kafa seti ile sanal gerçeklik ortamında deneyimlenmesi ve bir kez de sanal modelin düşük teknolojili gözlük ile sanal gerçeklik ortamında deneyimlenmesi şeklinde gerçekleştirilecektir. Bu testler esnasında

1

Figure C.2 : Pages of the Informed Consent Form.

görüntü, ses ve ekran kaydı alınacak olup bu kayıtlar kesinlikle araştırmacılar haricinde kimse ile paylaşılmayacaktır. Her testten sonra teknolojiyi test etme sürecine dair deneyimlerinizi tespit edebilmek için anket ve mülakat çalışmaları da testlerin akabinde gerçekleştirilecektir.

4. **Anket:**
   İlgili teknolojiyi kullanım deneyiminize dair verileri toplamaya dönük olarak gerçekleştirilecek olup önceden hazırlanmış soru formlarını doldurmanız şeklinde yürütülecektir. Anket, kesinlikle kişisel ve/veya mahrem bilgileri talep eden ya da sizi rahatsız edecek sorular içermeyecektir.
5. **Mülakat:**
   Mülakat çalışması da benzer şekilde kesinlikle kişisel ve/veya mahrem bilgileri talep eden ya da sizi rahatsız edecek sorular içermeyecektir. Mülakatlar yarı yapılandırılmış açık uçlu sorularla yüz yüze gerçekleştirilecek olup ilgili teknolojiyi kullanımınıza dair derinlemesine bilgi edinmeyi amaçlamaktadır. Mülakatlarda ses kaydı alınacak olup bu kayıtlar kesinlikle araştırmacılar haricinde kimse ile paylaşılmayacaktır.

OLASI RİSKLER VE RAHATSIZLIKLAR:
Kullanılacak teknoloji nadiren de olsa kısa süreli baş dönmesi ve/veya mide bulantısı ve/veya göz yorulması yapabilir. Bu gibi durumlarda çalışma anında sonlandırılacaktır. Bu nedenle ciddi ve/veya kalıcı bir rahatsızlık riski bulunmamaktadır.

TOPLUMA VE/VEYA DENEKLERE OLASI FAYDALARI:
İlgili teknoloji sanal modelin 1/1 ölçekte ve kesintisiz 3 boyut algısı ile gerçekçi bir şekilde deneyimlenmesine imkan vermektedir. Bu nedenle teorik olarak tasarım öğrencilerinin henüz fiziksel olarak var olmayan tasarımlarını herhangi bir fiziksel varlığa ihtiyaç duymadan görünür/algılanır kılmasına imkan vermektedir. Pratikte ise bu teknolojinin mevcut eğitim sistemine entegre olup olamayacağı, olabilecekse nasıl olabileceği konusu halen netlik kazanmamıştır. Bu çalışma ile ortaya çıkacak bilgiler endüstriyel tasarım eğitimi açısından önemli ve faydalı olarak değerlendirilebilir. Katılımcılar açısından ise bu yeni teknoloji ile erken aşamada tanışma ve deneme fırsatı sunmaktadır.

GİZLİLİK:
Bu çalışmayla bağlantılı olarak elde edilen ve sizinle özdeşleşmiş her bilgi gizli kalacak, üçüncü kişilerle paylaşılmayacak ve yalnızca sizin izniniz ile ifşa edilecektir. Gizlilik, verilerin ücretli bir bulut depolama hizmetinden faydalanılarak şifre korumalı olarak saklanması ve sadece araştırmacının erişimiyle sınırlı tutulması şeklinde sağlanacaktır. Araştırma sonuçları tüm gizlilik ilkelerine uyularak sadece bilimsel çalışmalarda kullanılacaktır.

KATILIM VE AYRILMA:
Bu çalışmanın içinde olmak isteyip istemediğinize tamamen bağımsız ve etki altında kalmadan karar veriniz. Bu çalışmaya gönüllü olarak katılmaya karar vermeniz halinde dahi, sahip olduğunuz herhangi bir hakkı kaybetmeden veya herhangi bir cezaya maruz kalmadan istediğiniz zaman çekilebilirsiniz.

Figure C.2 (continued) : Pages of the Informed Consent Form.

ARAŞTIRMACILARIN KİMLİĞİ:

Bu araştırma ile ilgili herhangi bir sorunuz veya endişeniz varsa, lütfen iletişime geçiniz:

Araş. Gör. Ahmet Hamurcu (Doktora Öğrencisi)
İstanbul Teknik Üniversitesi
[redacted]

Doç. Dr. Şebnem Timur Öğüt (Tez Danışmanı)
İstanbul Teknik Üniversitesi
[redacted]

Yukarıda açıklanan prosedürleri anladım. Sorularım tatmin olacağım şekilde yanıtlandı ve dilediğim zaman ayrılma hakkım saklı kalmak koşulu ile bu çalışmaya katılmayı onaylıyorum. Bu formun bir kopyası tarafıma verildi.

Tarih:

Katılımcının	Araştırmacıların	
Adı,Soyadı:	Ahmet Hamurcu	Şebnem Timur Öğüt
İmzası:		
e-posta:	hamurcua@itu.edu.tr	timurseb@itu.edu.tr
Telefon:	[redacted]	[redacted]

İletişim bilgilerimin diğer araştırmacıların benimle iletişime geçebilmesi için "ortak araştırma havuzuna" aktarılmasını

☐kabul ediyorum ☐kabul etmiyorum (lütfen uygun seçeneği işaretleyiniz)

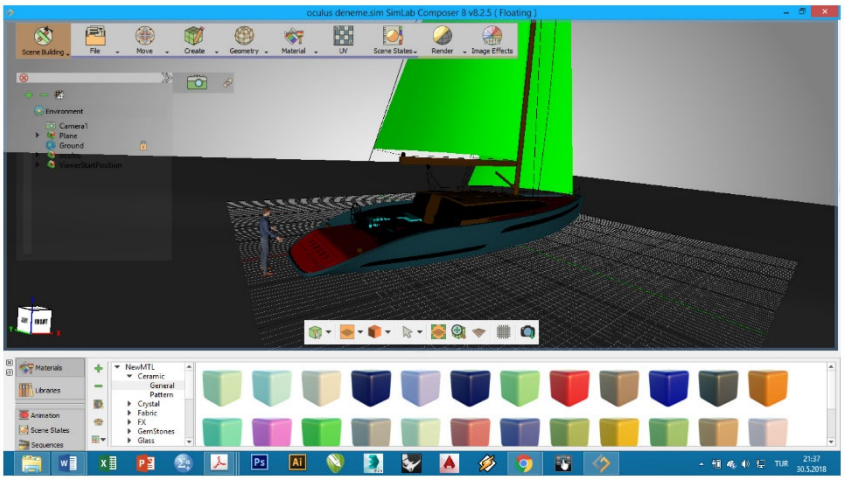
3

Figure C.2 (continued) : Pages of the Informed Consent Form.

3. Manual for Converting a VR Scene into a Format that is Experienceable on Mobile Devices

VR Sahnenizi Mobil Cihazlarda Görüntülenebilir Hale Getirme

1. Sahnenizi Simlab'da açın



2. "File" menüsü altındaki "Export" seçeneğine tıklayın

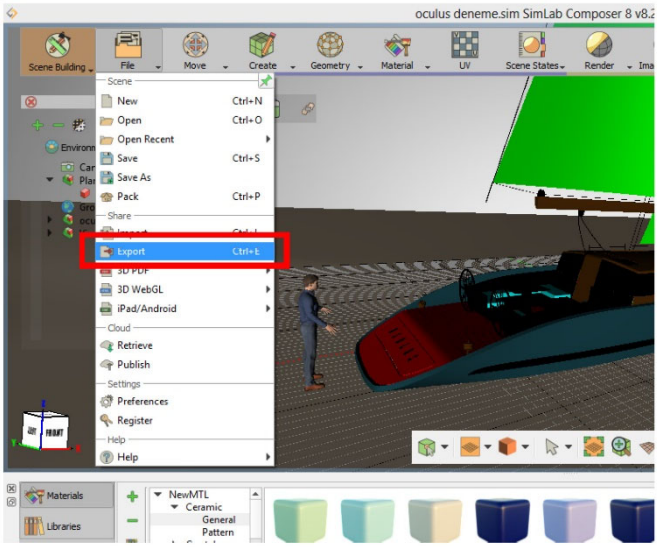
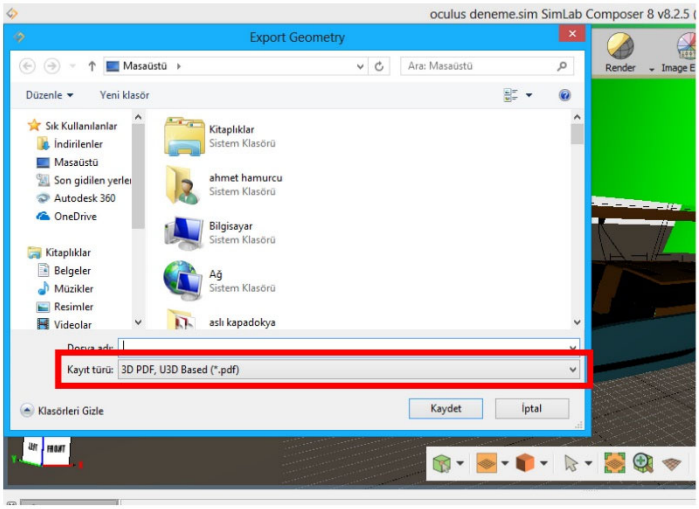


Figure C.3 : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

3. Açılan pencerede kaydetmeye başlamadan önce “Kayıt türü” açılır menüsünü tıklayın



4. Açılan menüden “Simlab VR ShowRoom File (*.vrzim)” seçeneğini tıklayın

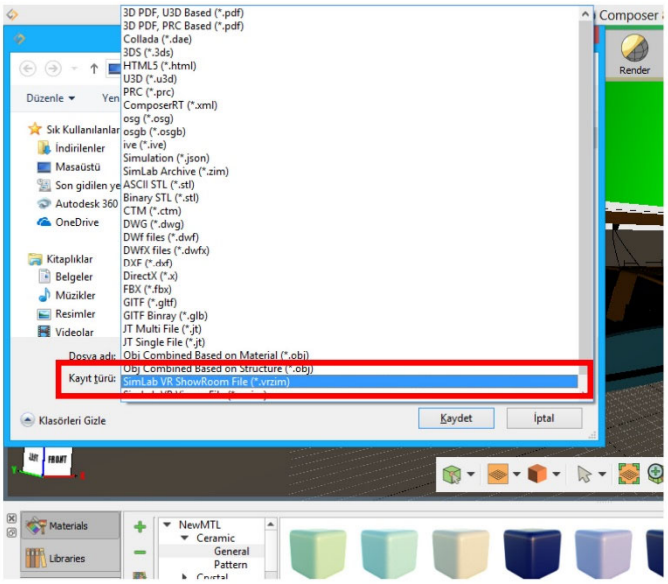
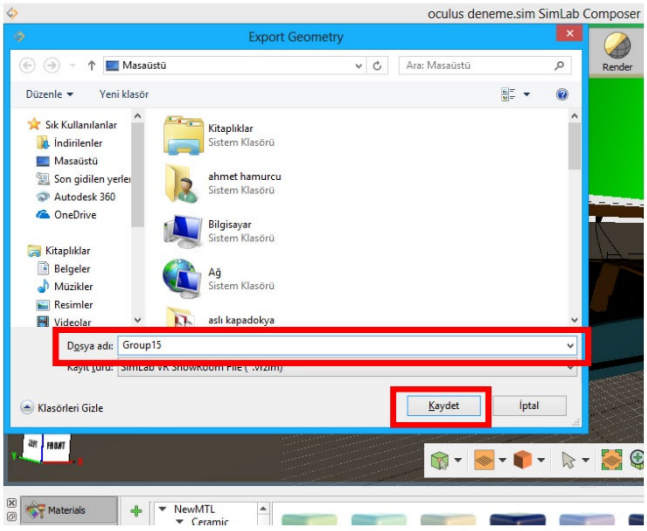


Figure C.3 (continued) : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

5. “Dosya adı” satırına grup numaranızı (örnek: Group15) yazdıktan sonra dosyanızı bilgisayarınızda kolay bulabileceğiniz bir yere kaydedin



6. Sonra Simlab’da “Scene Building” butonuna tıklayıp açılan menüden “Virtual Reality” seçeneğine tıklayın

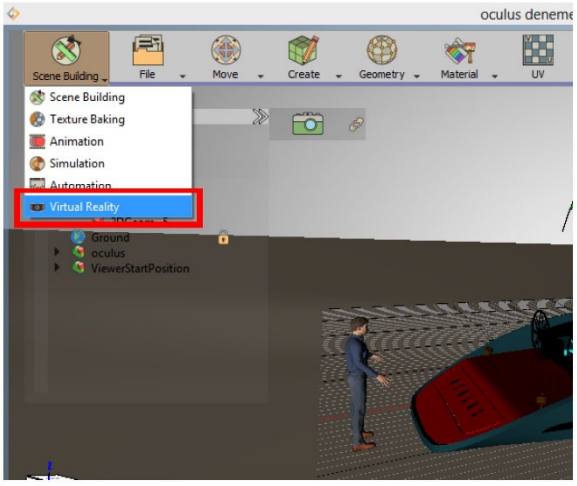
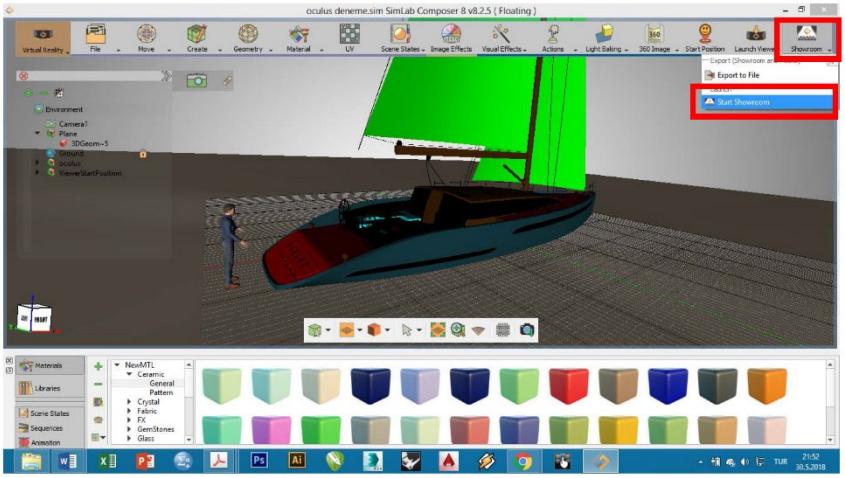


Figure C.3 (continued) : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

7. Sağ üst köşedeki “Showroom” butonuna tıklayarak açılan menüden “Start Showroom”mu seçin



8. Açılan pencerede önce sol üst tarafındaki “+” sembolüne tıklayın, ardından açılan küçük pencerede “Browse” butonuna tıkladıktan sonra az önce kaydetmiş olduğunuz .vrzim uzantılı dosyayı bulup seçtikten sonra “Add” butonuna tıklayın

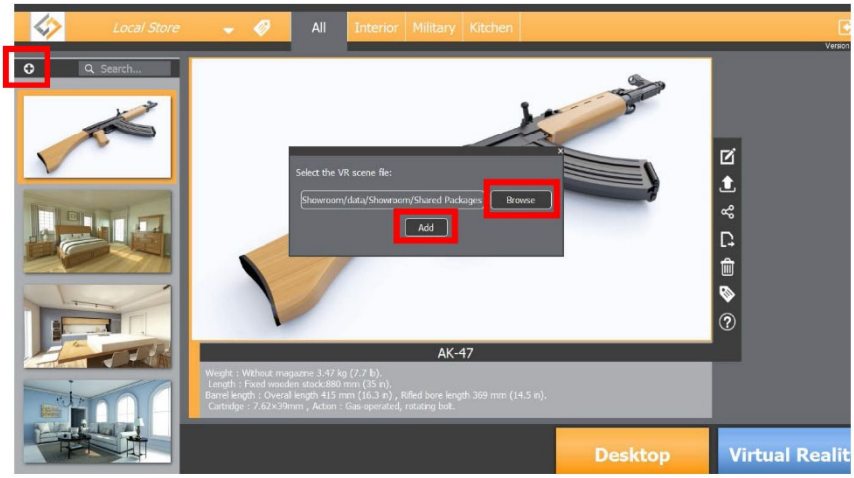
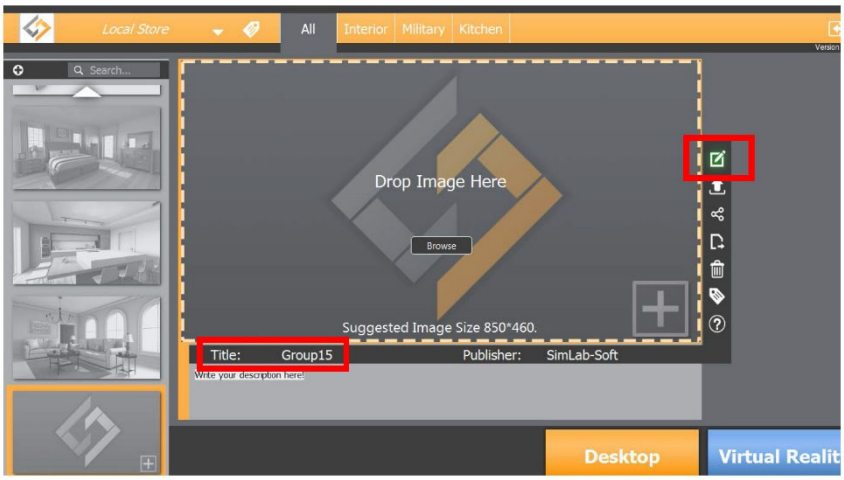


Figure C.3 (continued) : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

9. Karşınıza aşağıdaki gibi bir pencere gelecek. "Title" kısmında dosya adınızın yazdığından emin iseniz sağ taraftaki menünün en üstünde yer alan ikona (End Edit Mode) tıklayın.



10. Sonrasında yine sağ taraftaki menünün baştan dördüncü sırasındaki ikona (Pack Package) tıklayın

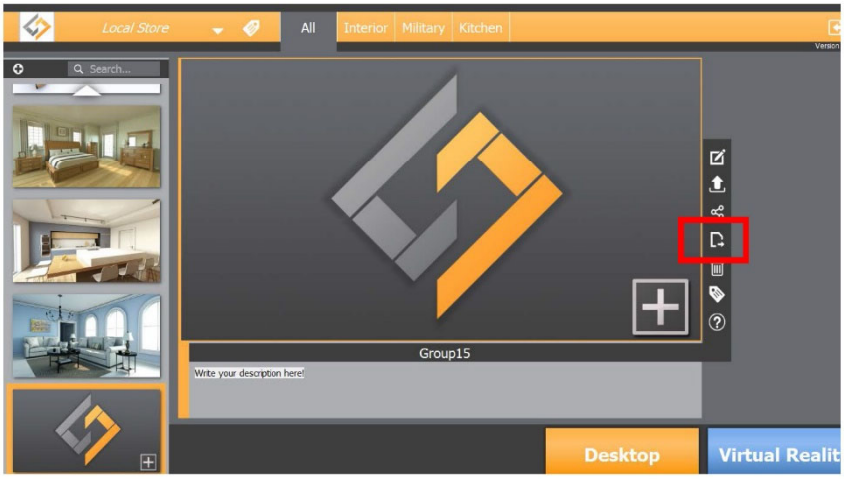


Figure C.3 (continued) : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

11. Açılan pencerede “Dosya adı” kısmına yine grup numaranızı (örnek: Group 15) yazarak bilgisayarınızda istediğiniz yere kaydedin. Böylelikle .vrpackage uzantılı dosyanız hazırlanmış olacak.

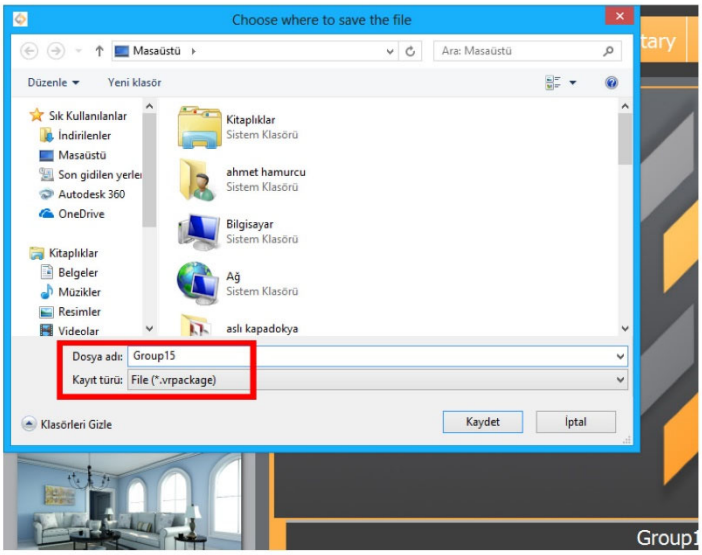


Figure C.3 (continued) : Pages of the manual for converting a VR scene into a format that is experienceable on mobile devices.

4. Consent Form for the Use of Personal Data

İŞİTSEL, GÖRSEL, SÖZLÜ ve YAZILI VERİLERİN KULLANIMI İÇİN İZİN FORMU

İstanbul Teknik Üniversitesi Mimarlık Fakültesi Endüstri Ürünleri Tasarımı Bölümü araştırma görevlisi Ahmet Hamurcu'nun doktora tezi kapsamında yürütülen ve öğretim üyesi Prof. Dr. Şebnem Timur Öğüt'ün tez danışmanı olarak yer aldığı "Kapsayıcı Sanal Gerçeklik Ortamlarında Kullanıcı Deneyiminin Ölçülmesi ve Tasarlanması" başlıklı araştırma kapsamında 2017-2018 Bahar Dönemi EUT 320E - Industrial Product Design III dersi süresince tarafımdan elde edilmiş her türlü işitsel, görsel, sözlü ve/veya yazılı verinin akademik çalışmalarda kullanımına izin verdiğimi beyan ederim.

01.06.2018

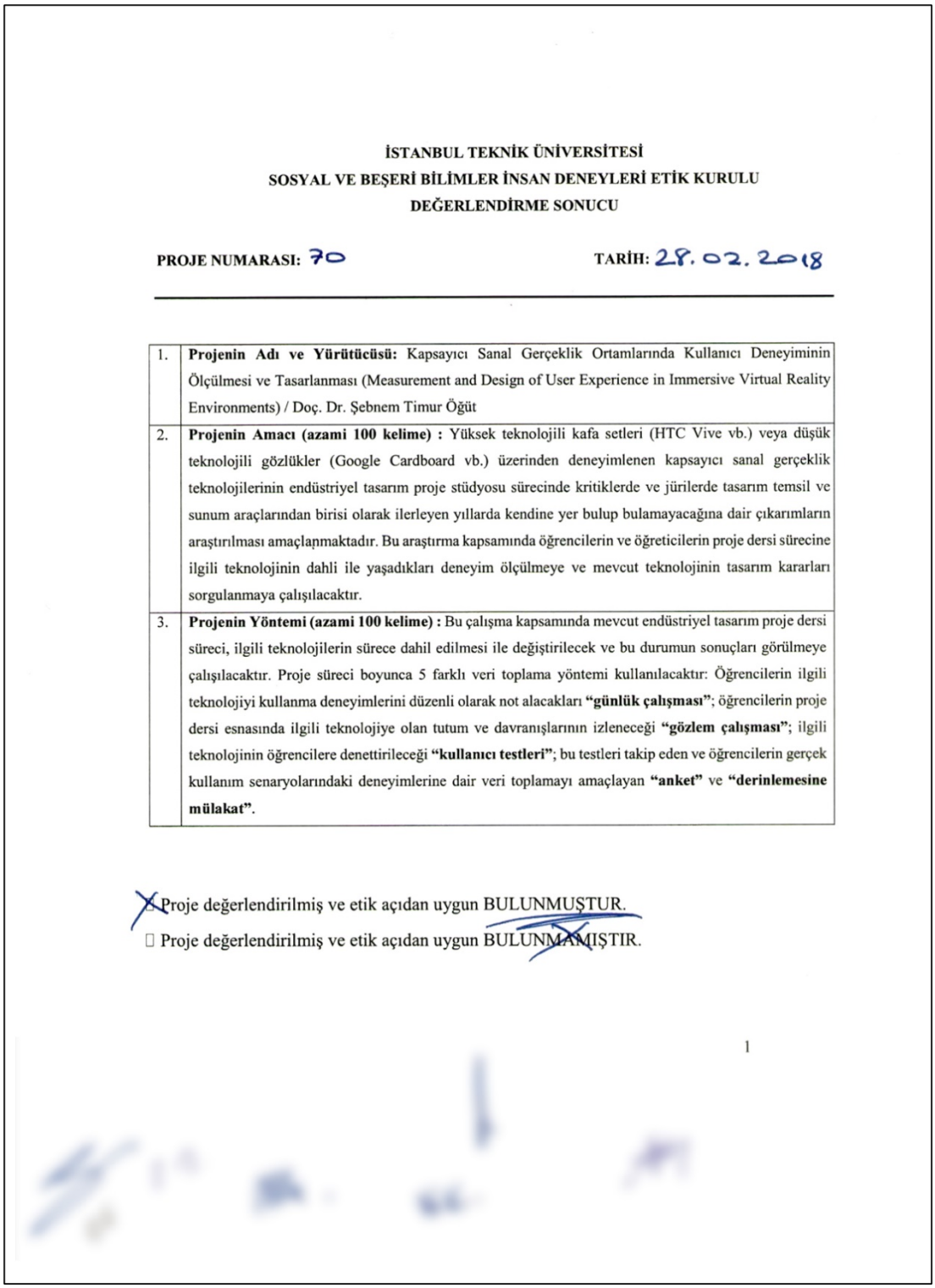
Adı Soyadı:

İmzası:

Figure C.4 : Consent form for the use of personal data.

APPENDIX D: Ethics Committee Approvals

1. The approval of ITU Humanities and Social Sciences Committee of Human Research Ethics



İSTANBUL TEKNİK ÜNİVERSİTESİ
SOSYAL VE BEŞERİ BİLİMLER İNSAN DENEYLERİ ETİK KURULU
DEĞERLENDİRME SONUCU

PROJE NUMARASI: 70 **TARİH:** 28.02.2018

1.	**Projenin Adı ve Yürütücüsü:** Kapsayıcı Sanal Gerçeklik Ortamlarında Kullanıcı Deneyiminin Ölçülmesi ve Tasarlanması (Measurement and Design of User Experience in Immersive Virtual Reality Environments) / Doç. Dr. Şebnem Timur Öğüt
2.	**Projenin Amacı (azami 100 kelime) :** Yüksek teknolojili kafa setleri (HTC Vive vb.) veya düşük teknolojili gözlükler (Google Cardboard vb.) üzerinden deneyimlenen kapsayıcı sanal gerçeklik teknolojilerinin endüstriyel tasarım proje stüdyosu sürecinde kritiklerde ve jürilerde tasarım temsil ve sunum araçlarından birisi olarak ilerleyen yıllarda kendine yer bulup bulamayacağına dair çıkarımların araştırılması amaçlanmaktadır. Bu araştırma kapsamında öğrencilerin ve öğreticilerin proje dersi sürecine ilgili teknolojinin dahli ile yaşadıkları deneyim ölçülmeye ve mevcut teknolojinin tasarım kararları sorgulanmaya çalışılacaktır.
3.	**Projenin Yöntemi (azami 100 kelime) :** Bu çalışma kapsamında mevcut endüstriyel tasarım proje dersi süreci, ilgili teknolojilerin sürece dahil edilmesi ile değiştirilecek ve bu durumun sonuçları görülmeye çalışılacaktır. Proje süreci boyunca 5 farklı veri toplama yöntemi kullanılacaktır: Öğrencilerin ilgili teknolojiyi kullanma deneyimlerini düzenli olarak not alacakları **"günlük çalışması"**; öğrencilerin proje dersi esnasında ilgili teknolojiye olan tutum ve davranışlarının izleneceği **"gözlem çalışması"**; ilgili teknolojinin öğrencilere denettirileceği **"kullanıcı testleri"**; bu testleri takip eden ve öğrencilerin gerçek kullanım senaryolarındaki deneyimlerine dair veri toplamayı amaçlayan **"anket"** ve **"derinlemesine mülakat"**.

X Proje değerlendirilmiş ve etik açıdan uygun BULUNMUŞTUR.

☐ Proje değerlendirilmiş ve etik açıdan uygun BULUNMAMIŞTIR.

1

Figure D.1 : The approval of ITU Humanities and Social Sciences Committee of Human Research Ethics.

2. The approval of ITU Health and Engineering Sciences Human Research Ethics Committee

İTÜ

İSTANBUL TEKNİK ÜNİVERSİTESİ-SAĞLIK VE MÜHENDİSLİK BİLİMLERİ
İNSAN ARAŞTIRMALARI ETİK KURULU (İTÜ-SM.İNAREK)

28 Şubat 2018

Reference No: 2018 / EÜT 1

İstanbul Teknik Üniversitesi Endüstri Ürünleri Tasarımı Bölümü öğretim üyelerinden Doç. Dr. Şebnem Timur Öğüt yürütücülüğündeki "Kapsayıcı Sanal Gerçeklik Ortamlarında Kullanıcı Deneyiminin Ölçülmesi ve Tasarlanması" adlı proje değerlendirilmiş ve etik açıdan uygun bulunmuştur.

Figure D.2 : The approval of ITU Health and Engineering Sciences Human Research Ethics Committee.

APPENDIX E: Additional Supportive Documents

1. The catalogue form of the course "EUT 320E Industrial Design Studio III"

İTÜ
DERS KATALOG FORMU
(COURSE CATALOGUE FORM)

Dersin Adı				**Course Name**		
Endüstriyel Tasarım Stüdyosu III				Industrial Design Studio III		
				Ders Uygulaması, Saat/Hafta (Course Implementation, Hours/Week)		
Kodu (Code)	**Yarıyılı (Semester)**	**Kredisi (Local Credits)**	**AKTS Kredisi (ECTS Credits)**	**Ders (Theoretical)**	**Uygulama (Tutorial)**	**Laboratuar (Laboratory)**
EUT 320E	6	5	9	2	6	0

Bölüm / Program (Department/Program)	Endüstri Ürünleri Tasarımı Industrial Product Design			
Dersin Türü (Course Type)	Zorunlu Compulsory	**Dersin Dili (Course Language)**	İngilizce English	
Dersin Önkoşulları (Course Prerequisites)	EUT 319E MIN DD veya EUT 315E MIN DD veya EUT 311E MIN DD			

Dersin mesleki bileşene katkısı, % (Course Category by Content, %)	**Temel Bilim (Basic Sciences)**	**Temel Mühendislik (Engineering Science)**	**Mühendislik Tasarım (Engineering Design)**	**İnsan ve Toplum Bilim (General Education)**
			100%	

Dersin İçeriği **(Course Description)**	Yenilikçi ve eleştirel bir konsept geliştirebilme; Bu konsepti sözlü, yazılı ve görsel bir şekilde ifade etme; Kültürel kimlik konuları; Çevresel ve ekolojik faktörler; Toplumsal sorumluluk; Ekip çalışması; Farklı disiplinlerle iletişim; Üretilebilirlik ve maliyetlendirme; Bir ürün ailesi yaratabilme; Ürünün satış senaryosunu oluşturabilme; Pazarlama, ambalaj gibi faktörleri göz önüne alma; Kullanım senaryoları geliştirebilme.
	Creating innovative and critical concepts; Verbal, written and visual expression of these concepts; The issues of cultural identity; The environmental and ecological factors; The social responsibility; Teamwork; Communication with different disciplines; Cost analysis and produce ability; Ability to create product family; Developing a product sales scenario; Considering the factors as marketing and packaging; Ability to develop scenarios for use
Dersin Amacı **(Course Objectives)**	1. Öğrencilerin yenilikçi ve eleştirel bir konsept geliştirebilmeleri ve bu konsepti sözlü, yazılı ve görsel bir şekilde ifade etmeleri amaçlanmaktadır. 2. Çevre, ekoloji ve sürdürülebilirlik konularını ileri düzeyde içeren tasarım çalışmaları yapılması amaçlanmaktadır. 3. Farklı disiplinlerle iletişim halinde bir ekip içinde tasarım çalışmaları yapılması amaçlanmaktadır. 4. Detaylı kullanım senaryoları geliştirme ve bir ürün ailesi oluşturma konusunda bilgilendirici tasarım çalışmalarının yapılması amaçlanmaktadır.
	1. It is aimed to support students to create innovative and critical concepts and to express them verbally and visually. 2. It is aimed to process design projects carefully including advanced subjects as enviorenment, ecology and sustainability. 3. It is aimed to process design projects within a design team in communication with different disciplines. 4. It is aimed to process design projects informing students about developing detailed scenarios of use and creating a product family.
Dersin Öğrenme Çıktıları **(Course Learning Outcomes)**	Öğrenciler 1. Geliştirdikleri konseptleri görsel ve sözlü olarak profesyonelce savunabilirler 2. Farklı disiplinlerle iletişim halinde bir ekip içinde tasarım çalışmaları yapabilirler 3. Detaylı kullanım senaryoları geliştirebilir ve ürün ailesi oluşturabilirler 4. Çevresel ve toplumsal sorumluluk konularında tasarım önerileri geliştirebilirler 5. Tasarım sürecini hedeflenen amaç yönünde etkin bir şekilde yönetebilirler
	Students will be able to, 1. Create innovative concepts and defend them visually and verbally in a professional way 2. Process design projects within a design team in communication with different disciplines 3. Develop detailed scenarios of use and create a product family 4. Develop product proposals on subjects as environmental and ecological responsibility 5. Effectively manage the design process towards the project objectives

Figure E.1 : Pages of the catalogue form of the course "EUT 320E Industrial Design Studio III".

Ders Kitabı (Textbook)			
Diğer Kaynaklar (Other References)	Quire S., and Byrne B., 2002. *Creating Breakthrough Ideas: The collaboration of anthropologists and designers in the product development industry*, Westport, Conn.: Bergin & Garvey Russel, B., 2006. *Design & Make it: Product Design KS4*, Cheltenham: Nelson Thornes Press, M., 2003. *The Design Experience: The role of design and designers in the twenty-first century*, Aldershot, Hants: Ashgate. Coleman, R., 2007. *Design for Inclusivity: A practical guide to accessible, innovative and user-centred design*, Aldershot: Gower Krippendorff, K. 2006. *The Semantic Turn: A New Foundation for Design*, USA: CRC Press. Roozenburg, N.F.M., Eekels, J. 1995. *Product Design: Fundamentals and Methods*, John Wiley & Sons Ltd.		
Ödevler ve Projeler (Homework & Projects			
Laboratuar Uygulamaları (Laboratory Work)			
Bilgisayar Kullanımı (Computer Use)	Bilgisayar kullanımı zorunludur. Computer use in this course is compulsory.		
Diğer Uygulamalar (Other Activities)	Yok None		
Başarı Değerlendirme Sistemi **(Assessment Criteria)**	**Faaliyetler (Activities)**	**Adedi (Quantity)**	**Değerlendirmedeki Katkısı, % (Effects on Grading, %)**
	Yıl İçi Sınavları (Midterm Exams)		
	Kısa Sınavlar (Quizzes)		
	Ödevler (Homework)		
	Projeler (Projects)	1	40
	Dönem Ödevi/Projesi (Term Paper/Project)		
	Laboratuar Uygulaması (Laboratory Work)		
	Diğer Uygulamalar (Other Activities)		
	Final Sınavı (Final Exam)	1	60

DERS PLANI

Hafta	Konular	Dersin Çıktıları
1	Proje konusunun bildirilmesi ve tartışılması	1, 3
2	Kültürel bağlam, kullanıcı ve teknoloji araştırmalarının yapılması	2, 3, 4, 5
3	Kültürel bağlam, kullanıcı ve teknoloji araştırmalarının yürütülmesi	2, 3, 4
4	Araştırmaların sözlü, yazılı ve görsel olarak sunulması ve paylaşılması	1, 2
5	Konsept geliştirme çalışmalarına başlanması	3, 4, 5
6	Konsept geliştirme çalışmalarının ilerletilmesi	3, 4
7	Konsept sunumu	1, 2
8	Ürün programının, üretim, pazarlama ve kullanım senaryolarının geliştirilmesi	2, 3, 5
9	Sürecin ve senaryoların belirli bir ürün önerisine ulaşma yönünde değerlendirilmesi	2, 3, 5
10	Tasarım detaylandırma, kullanım ve üretim	3, 4
11	Tasarım detaylandırma, kültür, sürdürülebilirlik ve çevre	2, 3, 4
12	Tasarım sonuçlandırma, teknik meseleler	2, 3, 4
13	İki ve üç boyutlu modelleme çalışmaları	1, 3
14	Sonuç ürün öncrisinin sözlü, yazılı ve görsel olarak sunumu	1, 2

Figure E.1 (continued) : Pages of the catalogue form of the course “EUT 320E Industrial Design Studio III”.

COURSE PLAN

Weeks	Topics	Course Outcomes
1	Introduction to the project brief and discussion	1, 3
2	Planning the user research on cultural context, user and technology	2, 3, 4, 5
3	Proceeding the user research on cultural context, user and technology	2, 3, 4
4	Verbal, written and visual presentation of the research results	1, 2
5	Starting concept generation	3, 4, 5
6	Proceeding concept generation	3, 4
7	Concept presentation	1, 2
8	Developing the product program and scenarios of production, marketing and use	2, 3, 5
9	Evaluating the process and the scenarios towards a specific product proposal	2, 3, 5
10	Design detailing, use and production	3, 4
11	Design detailing, culture, sustainability and environment	2, 3, 4
12	Finalizing design, technical issues	2, 3, 4
13	Two and three dimensional modelling	1, 3
14	Verbal, written and visual presentation of the final product proposal	1, 2

Dersin Endüstri Ürünleri Tasarımı Programıyla İlişkisi

	Programın mezuna kazandıracağı bilgi ve beceriler (programa ait çıktılar)	Katkı Seviyesi		
		1	2	3
1	Gözlem yapma, problem tanımlama ve ayrıştırma bilgi ve becerileri			X
2	Tasarım sürecinin her aşamasında her yönüyle araştırma, bilgi toplama ve analizinin temel yöntemlerini uygulayabilme becerisi			X
3	Yaratıcı problem çözme yöntemlerini sistematik olarak kullanmaya yönelik bilgi ve becerisi			X
4	Yenilikçi ve kullanım değeri olan ürün ve sistemlere yönelik tasarım konseptleri oluşturma becerileri			X
5	Verili bir süre içinde yeterli sayıda ve nitelikte konsept seçeneği üretme ve geliştirme becerileri			X
6	Tasarım konseptlerinin görselleştirmesi için gereken serbest el ve yardımcı araçlara dayalı bilgi ve beceriler		X	
7	3 ve 4 boyutlu model ve prototip yapımına yönelik temel bilgi ve becerisi		X	
8	Fikir ve konseptlerini yazılı ve sözlü olarak paylaşma bilgi ve becerisi			X
9	Kullanıcıyı ve kullanım süreçlerini anlamaya yönelik araştırma bilgi ve becerisi			X
10	Kullanıcının fiziksel, psikolojik, ergonomik, kültürel ve sosyal ihtiyaçlarına kavrama becerisi			X
11	Anlamlı biçim yaratma ve geliştirme becerisi			X
12	Malzemeleri tanıma, değerlendirebilme, seçebilme ve kullanabilme bilgi ve becerisi			X
13	Çağdaş imalat yöntemleri konusunda bilgilenme		X	
14	Bilgi teknolojilerinin kullanımı ve yorumlanması konusunda temel bilgi ve becerisi		X	
15	Teknolojiyi yorumlayarak yaratıcı tasarım çözümleri geliştirebilmeye yönelik bilgi ve becerisi			X
16	Firma kültür ve stratejilerini anlama ve yorumlayabilme becerisi		X	
17	Tasarım proje sürecini planlama ve yönetme becerisi			X
18	Farklı disiplinlerden uzmanlarla ekip içinde etkin çalışabilme becerisi			X
19	Piyasa koşulları ve eğilimlerini anlayıp yorumlama bilgi ve becerisi		X	
20	Tasarım sürecinde içinde sentezci ve girişimci olabilme ve liderlik becerileri		X	
21	Genel olarak hem doğal hem de insan yapımı çevreye karşı analitik yaklaşabilme bilgi ve becerisi			X
22	Tasarımın sosyo-kültürel-ekonomik, çevresel bağlamı konusunda bilgilenme.			X
23	Değişen yaşam biçimleri ve bunların farklı sektörlerdeki yansımalarını izleme ve yorumlayabilme becerileri			X
24	Görsel estetik değerleri kavrama becerisi		X	
25	Dinlemeye, anlamaya, araştırmaya ve eleştiriye açık olma, dolayısıyla kendini yenilemeyi başarabilme becerisi			X
26	Kendi başına öğrenme becerileri		X	
27	Yerel kültürel değerleri tasarım sürecinde girdilere dönüştürebilme becerileri		X	
28	Mesleki etik ilkelerine yönelik bilgilenme		X	
29	Mesleğinin dünyadaki ve Türkiye'deki tarihsel gelişimi konusunda bilgilenme	X		
30	Hukuki hak ve sorumlulukları konusunda bilgilenme	X		
31	Mesleki terminolojiyi Türkçe ve İngilizce olarak yetkin şekilde kullanabilme bilgi ve becerisi			X
32	Türkiye'nin kalkınmasında tasarımın rolü konusunda aktif bir yaklaşımın geliştirilmesine yönelik bilgilenme.	X		

1: Az, 2. Kısmi, 3. Tam

Figure E.1 (continued) : Pages of the catalogue form of the course "EUT 320E Industrial Design Studio III".

Relationship between the Course and Industrial Product Design Curriculum

	Program Outcomes	Level of Contribution		
		1	2	3
1	Observation, problem identification and decomposition knowledge and skills			X
2	Skills in research, information gathering and analysis methods in every stage of the design process.			X
3	Knowledge and skills in systematic application of creative problem solving methods			X
4	Skills of conceiving design concepts for innovative product and services			X
5	Skills of creating and developing sufficient number of alternative design concepts in a given time period.			X
6	Knowledge and skills for employing manual and computer-aided visualization of design concepts		X	
7	Knowledge and skills for 3D and 4D models, and prototyping.		X	
8	Knowledge and skills in verbal and written communication of ideas and concepts.			X
9	Research skills for deep understanding of users and their related processes			X
10	Knowledge and skills for understanding physical, psychological, ergonomics, cultural and social needs of users.			X
11	Skills for creating and developing meaningful product forms			X
12	Knowledge and skills in evaluating, choosing and using materials.			X
13	Knowledge in modern manufacturing methods.		X	
14	Knowledge and skills in evaluating and using information technologies		X	
15	Knowledge and skills for developing creative design solutions on the basis new technology			X
16	Knowledge and skills in understanding and assessing company strategies and culture		X	
17	Planning and managerial skills for industrial design projects			X
18	Multidisciplinary teamwork skills			X
19	Knowledge and skills in understanding market dynamics and trends		X	
20	Entrepreneurial and leadership skills in design		X	
21	Knowledge and skills for developing analytical approaches to natural and artificial environment			X
22	Knowledge about the social, cultural economic and environmental context of industrial design			X
23	Skills for observing, capturing and evaluating the changing life styles, and their reflections			X
24	Apprehensive skills for visual aesthetic values		X	
25	Developing attitudes for listening, inquiring, understanding, being open for critique and self-development and renewal			X
26	Skills for self-learning		X	
27	Skills for transforming local cultural values into design inputs.		X	
28	Knowledge about professional ethics in industrial design		X	
29	Knowledge about the historical development of industrial design in Turkey and the World.	X		
30	Knowledge about the legal rights and responsibilities of industrial designers	X		
31	Effective use of professional design terminology			X
32	Knowledge about the role of industrial design for the social and economic development of Turkey	X		

1: Little, 2. Partial, 3. Full

Düzenleyen (Prepared by)	*Tarih (Date)*	*İmza (Signature)*

Figure E.1 (continued) : Pages of the catalogue form of the course "EUT 320E Industrial Design Studio III".

APPENDIX F: Excerpts from the Interviews

1. Excerpts from the first-round interviews

Table F.1 : An excerpt related to prejudgments about VR use in the jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	I had some reservations about VR. Will it be used? Will it really be needed? Will students prepare VR scenes, and will jurors experience them? I had question marks. It was something I didn't know. And I actually thought it would not happen, even though we were so curious about it. But the opposite of my thoughts happened.

Table F.2 : Excerpts related to the effects of VR use in the jury session on the motivations and performances of the students.

Juror or Student	Excerpts from the transcription of interview records
J1	The students were very well prepared [for the jury].
J1	In preliminary juries, students usually present rudimentary representations, such as hand-drawings and mock-ups, belonging to an unfinished design so that they have something to add to the next jury, or they can be freer if they need to change something. However, this time it was not like that. We saw interiors and seating units that were almost finished and modeled in detail.
J1	I found the students to be more enthusiastic than I expected.
S2.1	We tried to create a good CAD model, a detailed CAD model.
S3.1	We worked really hard to create a high-quality CAD model. CAD modeling accounted for almost eighty percent of the work. One of the reasons we devoted so much time to create the CAD model was that it would be experienced by the jurors in the VR environment.
S5.3	The fact that the jury members would experience our design in 3 dimensions both motivated and made us happy.

Table F.3 : Excerpts related to the effects of using VR in the jury session on the design sheets of the students.

Juror or Student	Excerpts from the transcription of interview records
J1	Basic views, for example, were missing in the sheets. There was no top view. Section drawings were missing. When we asked “Why didn't you put them in your sheets?”, they answered "We didn't put them because the projects would be looked at in VR". However, that information was the kind of information we could not obtain in VR. Because in VR, we can only get a perspective view.
J1	It was obvious that there had been some negligence in the preparation of the design sheets.
J2	I thought there were a lot of shortcomings on the sheets. I think these shortcomings are due to the use of VR in the jury session.
J3	There were many deficiencies in the sheets.

Table F.3 (continued) : Excerpts related to the effects of using VR in the jury session on the design sheets of the students.

Juror or Student	Excerpts from the transcription of interview records
S1.1	In the jury session, we had noticed that we omitted to put our design proposal regarding the seating unit on any of our sheets.
S2.3	There was no top view on our sheets.
S2.2	Actually, we had forgotten to draw it.
S2.3	But then we thought they will see it in the VR scene, but our VR scene couldn't be run.
S3.2	We didn't put some information on our sheets since they already would be seen in our VR scene.
S3.1	There was no rendering of our design on our sheets. We did not put them on the sheets since we thought that our design would already be seen in the VR environment.
S7.1	We had forgotten to put some drawings on our sheets, but we thought that they already existed in our VR scene, and they would see them while experiencing it.
S8.1	While we were preparing our sheets, we planned to show some parts in VR. That's why we didn't put them on the sheets. In other words, we didn't put the things that we thought would be better understood in VR on our sheets.
S9.2	We did not consider presenting the information about the real dimensions on the sheets. Because we thought that it could be perceived in VR.
S10.1	We did not put too much detail on our sheets as they could be seen in VR.

Table F.4 : Excerpts related to the effects of VR use in the jury session on the design evaluation of jurors.

Juror or Student	Excerpts from the transcription of interview records
J1	Wearing the glasses and being in that virtual model made me understand very well what the students were trying to do, and I saw the effort and many details from inside. I realized that we have overlooked many things until today. Because I have experienced that a 3D model cannot be read that way on a design sheet. It cannot be read from the screen that way either. Getting into a 1/ 1 scale model has been a completely different experience.
J1	If there is a jury member left who has evaluated that project just by looking at those poorly prepared sheets, it is unfair to the student. Because there is a good model out there. The real information is there. If a juror doesn't experience it in VR, it means this juror will make his/her assessment without getting that information.
J1	How much of the project the student thought and realized? How close s/he tried to bring it to reality? In other words, the performance of the student can be seen very clearly. I see that the more detailed representation there is, the more s/he has worked and thought about. Accordingly, you have the opportunity to give more feedback. The jury duration is getting longer, but the quality of the detail we talked about increases.
J2	Very useful for jurors. I easily understood the issues that I did not fully understand on the sheets and in the oral presentations of the students.
J3	If these glasses were not used in the jury session, we would have been limited with the presentation skills of the students.
J5	It enabled us to capture the details that were missing on the design sheets or were not mentioned in the oral presentations.

Table F.4 (continued) : Excerpts related to the effects of VR use in the jury session on the design evaluation of jurors.

Juror or Student	Excerpts from the transcription of interview records
S2.2	I think it offers a much more comfortable way for the jurors to evaluate the design. I mean, trying to understand something by looking at things on two-dimensional sheets is more difficult for them.
S5.3	What some of our friends in other groups said was not understood by the jurors, but when they wore VR glasses, they said "Wow! So this is actually such a thing". They were surprised.

Table F.5 : Excerpts related to the effects of VR use in the jury session on the communication between the jurors and both the students and the designs.

Juror or Student	Excerpts from the transcription of interview records
J1	I think it enhanced our communication with the students and designs.
J2	VR enabled us to give more helpful feedback to students.
S2.1	I think it is a very effective tool for communication. Because what is presented on the sheets can sometimes be misunderstood by the jury members.
S3.1	It provided us great convenience.
S5.3	I think it is a good tool for us to express ourselves more accurately.
S8.2	We thought some details that we couldn't clearly explain verbally would be better understood by the jury members thanks to VR.
S9.2	The difference in our design was that the distance between the seats was set so that the passengers could pass comfortably. We cannot get the jurors to evaluate this comfort with sheets.
S10.1	We thought our design would be better understood. Because our drawings may not be explanatory enough. There may also be things that we have difficulty explaining verbally. But it is highly informative to be able to see everything in the three-dimensional VR environment at that moment.

Table F.6 : Excerpts related to why the jurors needed to experience some of the VR scenes.

Juror or Student	Excerpts from the transcription of interview records
J1	Because of the missing content on the design sheets, I needed to experience the VR scenes to understand what the students made.
J1	I experienced the VR scenes because the drawings were bad. If the drawings were good, and this time I would wonder how it looks in VR.
J5	It enabled us to capture the details that were missing on the design sheets or were not mentioned in the oral presentations.

Table F.7 : Excerpts related to why the jurors experienced only a few of the VR scenes, not all of them.

Juror or Student	Excerpts from the transcription of interview records
J1	I guess I didn't experience every VR scene. There was time pressure, and someone else was experiencing it. Because I could see what the person experiencing the VR scene saw on the screen, so even if I didn't experience all VR scenes, I always looked at the screen there with the corner of my eye while others were experiencing the VR scenes. So, I don't consider myself as having not experienced those VR scenes.
J2	I did not look at them all. Actually, I would like to look at all of them, but the jury should proceed fast. But even though I didn't experience all VR scenes myself, I watched them on the computer screen while the other jurors experiencing them. That's why I didn't need to experience some of them.
J3	I wanted to experience all VR scenes, but I did not experience any of them. Because if all jury members experienced all VR scenes, that jury session would not end.
J4	Experiencing the design in the VR environment when other jurors were commenting on that design via the design sheets caused a loss of focus on both the students and other jurors. Jury members should feed off each other and not lose their concentration.
J5	Experiencing the projects in the VR environment caused the process to slow down.
J5	Experiencing the VR scene while the students were going on presenting design ideas caused them to hesitate whether to continue their presentation or wait for that juror finished experiencing the VR scene.

Table F.8 : Excerpts related to students' feels and thoughts that emerged when their VR scenes were not experienced by one juror or more than one juror.

Juror or Student	Excerpts from the transcription of interview records
S2.2	Our VR scene could not be run. So, I was so sorry. Because I was excitedly waiting for that our VR scene was experienced by the jurors. Because we had put a lot of effort into modeling, and I wanted the jurors to see our model.
S2.2	No. Not only because we had put a lot of effort into it, but also because the jury members couldn't see it. If they had seen it, they could understand our project better.
S3.1	No, not all of them. Only two jurors looked at our VR scene.
S3.2	I wish they all had experienced it. Because our sheets were very insufficient. While one of the jury members was commenting on our project, I thought that if she had experienced our VR scene, she would have understood it better.
S3.3	I thought that some things were not fully understood. I thought the jury members who didn't look at our VR scene missed some things out.
S4.2	No, not all of them. Only one juror looked at our VR scene.
S4.1	When some jury members did not look at our VR scene, we wondered if they understood our design correctly.
S5.1	Our design was available as a whole in the VR environment. It also included things that were not on the sheets. So, I thought the jury members who did not experience our VR scene lacked some things.
S5.2	I wish they all had looked at our VR scene.
S6.2	They didn’t look at our VR scene.
S6.1	None of them looked at it.

Table F.8 (continued) : Excerpts related to students' feels and thoughts that emerged when their VR scenes were not experienced by one juror or more than one juror.

Juror or Student	Excerpts from the transcription of interview records
S6.2	They evaluated our project as far as they saw the things on the sheets.
S6.1	They tried to understand just by looking at the sheets.
S6.3	In this respect, this was an unfair jury evaluation.
S6.1	We felt bad.
S7.1	None of the jurors looked at our VR scene. I wish we did not prepare the VR scene. I thought our effort was wasted when they did not look at it.
S8.2	None of them looked at our VR scene. I thought that our project was not fully understood. Honestly, it made me feel a little bad. Because I felt as if our presentation was left half-finished.
S10.1	Our VR scene was not experienced by the jurors. This made us happy because so many things were missing in it.

Table F.9 : An excerpt related to why the jury members used the VR headset by holding it like binoculars with one hand rather than by wearing it properly.

Juror or Student	Excerpts from the transcription of interview records
J1	Because we used the VR headset not to play games for hours, but to examine projects with a specific purpose. And, there were those who were waiting for their turn to use it. For this reason, we acted as taking a quick look at the things we wanted to look at.

Table F.10 : Excerpts related to the comparison of evaluating a design by watching it in a video animation or experiencing it in a VR scene.

Juror or Student	Excerpts from the transcription of interview records
J1	I think the two are different from each other. For example, you pay attention to something in the drawing, let's suppose that the distance between two things seemed too small. When you look at that with glasses, you have the chance to view it from different angles, but in the video, the camera moves in a predetermined path. They are not the same. So, I can teleport myself wherever I want according to my need. Or I can go backward; I can go forward. I think it gives people freedom. Or I can create that video at that time with the camera angles I want, not the camera angles s/he wants.
J2	These two are not the same. Experiencing the VR scene is more useful than watching a video animation. Even watching what someone else sees on the screen while s/he is experiencing a VR scene is better than watching a video animation. Because I can't interfere with that video animation. But I can direct the person experiencing the VR scene. I can ask her/him to look at where I want to see.
J3	They are not the same. It was a 2-minute video. Whatever was shown in those two minutes, I could only see them. There was a situation of being selected. The route was selected, the frames shown were selected.

Table F.11 : Excerpts related to the way of VR use in this jury session, and demands for the next jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	It was used easier than I expected. It was not exhausting.
J1	It would be nice not to have to stand up every time. Because you are moving while experiencing a VR scene. You may distract the attention. Of course, I prefer to use it by sitting in my chair. Or we could have screens in front of us to be able to watch what a person sees while experiencing the VR scene. When it was our turn, others could watch what we see while experiencing it. I think it can be done with a single VR headset and multiple monitors.
J1	Since there was only one VR headset, the jury members could not use it at the same time or whenever they wanted. I guess I haven't experienced every VR scene. There was time pressure, and someone else was experiencing it.
J1	Others should be able to see what the person with the VR glasses sees while s/he is experiencing the VR scene.
J2	Since I was not the person installing the system, I do not think it had any difficulty for me. But it is very difficult for the person installing it and very difficult to manage. I think any jury member as well had no difficulty in using it.
J2	Seeing the computer screen was difficult for me. Because the screen was far away from me. I had to stand up whenever I wanted to see something.
J3	It was time-consuming and complicated.
J3	The jury session was going on when a juror wore the VR headset to experience a VR scene. And that jury member was no longer there. He had lost contact with the ongoing discussion between the jurors and students.
J3	The computer screen was not big enough. Hence, the other jury members could not see enough of what a juror was seeing while experiencing the VR scene.
J3	Each jury member should have equal access to the CAD models of the students. So, the VR scenes should be able to be equally experienced by all jury members.
J4	It should only be used when needed.
J4	A jury member should be able to contribute to the jury discussion by commenting and showing the things in the VR environment.
J4	The image of the VR environment should be clearly seen by other members.
J4	The VR experience area should be much more comfortable and safe.
J5	The VR scenes could not be experienced by all jury members at the same time.
J5	Others could not see what the jurors see while they were experiencing the VR scene.
J5	It would be better to experience VR scenes right after the end of the presentations.
J5	The areas reserved for presentations and VR experience should be separated from each other.
J5	What the jurors see while they were experiencing a VR scene should be projected on a screen or wall so that others can see it.
S2.1	While someone was experiencing the VR scene, others were waiting, so we were all waiting. It caused wasting time.
S2.3	I wish we could see what they saw while they were experiencing it. But not everyone could see it on the small screen. It may be projected on the wall for the next time. So audiences as well can see it.
S2.2	I think a larger space is needed.

Table F.11 (continued) : Excerpts related to the way of VR use in this jury session, and demands for the next jury session.

Juror or Student	Excerpts from the transcription of interview records
S3.1	The VR scenes were experienced one by one in turn by the jurors. This caused some troubles and consuming time.
S3.1	It needs to be a convenient system for us to show and explain the things in the VR scene.
S4.1	Experiencing the VR scene by each juror takes a lot of time. Also, the juror wearing VR glasses was isolated from the environment and couldn't listen to the jury dialogs. There were problems in terms of time and concentration.
S4.3	As a few jurors dealt with something else (VR) while the presentation was going on, the students who were presenting their designs inevitably got distracted.
S5.1	Using just one VR headset is not effective.
S6.1	They did not experience our VR scene in the jury session. Because it was taking time.
S6.3	It seemed unsystematic. Someone was trying to wear the glasses but could not. Then he was asking for your help. Then everything was getting messed up. The jury's attention was distracted. There was a lot of distraction in the jury session. The students were trying to go on, but he's looking at something else there. Another juror was telling you something. The students could not go on. I've seen such situations. Also, the cable mess as well bothered me a lot.
S6.3	I wish there was a presentation of the VR scene in a way that everyone can see. For example, students make their presentations inside their VR environment, they show the details they wanted to show, and everyone can see the things in the VR scene through their eyes.
S7.1	Using the VR headset was easy, but it took time for the jurors to use it one by one. I mean it's easy but time-consuming.
S8.2	I want while someone is using the VR glasses, others can see what s/he sees.
S10.2	Using only one VR headset caused some troubles.
S10.1	We were being able to watch what the jury member with VR glasses sees on the computer screen. However, not everyone could watch that screen since it was too small.
S10.2	It should be better to project that screen onto the wall.

2. Excerpts from the second-round interviews

Table F.12 : Excerpts related to the comparison of the proposed ways of VR use in the first and second cycle.

Juror or Student	Excerpts from the transcription of interview records
J1	The second one was more practical.
J2	This time, experiencing the VR scenes was more comfortable.
J4	This one was more practical and efficient. It was better.
J5	There was a more cumbersome structure in the previous jury session. We got rid of this cumbersome structure in this jury session.
S1.1	I think using VR was more difficult for the jurors in the previous jury session.
S2.1	This was better. We lost less time.

Table F.12 (continued) : Excerpts related to the comparison of the proposed ways of VR use in the first and second cycle.

Juror or Student	Excerpts from the transcription of interview records
S3.1	The second one seemed easier.
S3.3	I think the second one was more useful.
S4.1	The time wasted less.
S5.1	This time, our VR scenes were experienced by more jurors for a longer period of time. I think it is more efficient.
S6.1	I think this was definitely more efficient in terms of time.
S7.1	The second one was easier.
S8.2	This one was better. It seemed more useful in terms of time.
S9.1	In the second one, the jury process was more fluent.
S10.1	I think the second one provided a greater convenience for the jury members.

Table F.13 : Excerpts from the jurors' responses to the second question in Table 5.20.

Juror or Student	Excerpts from the transcription of interview records
J1	I guess I looked at all of them this time. Because we were able to look more easily without leaving our chairs since this was handier.
J2	I cannot remember the exact number, but I did not look at some of them. Because I was dealing with other things related to the jury flow at the same time. Also, I had to go out for a while. So I couldn't look at some of them. So it wasn't because of the way of VR use in the jury session.
J4	I experienced all projects in this jury session. This is because it can be done quickly without standing up.
J5	I experienced all projects in this jury session.

Table F.14 : Excerpts from the students' responses to the second question in Table 5.20.

Juror or Student	Excerpts from the transcription of interview records	Annotation by the researcher
S1.1	I am not sure. I am someone who gets very excited while giving presentation. So I didn't pay attention whether they looked at our VR scene.	*The VR scene of Group 1 was experienced by two jurors.*
S1.2	I do not remember anyone looking at our VR scene.	
S2.2	We could not notice whether they looked while giving presentation.	*The VR scene of Group 2 was experienced by all jurors.*
S2.1	Yes, we couldn't notice.	
S3.1	I can't remember exactly.	*The VR scene of Group 3 was experienced by three jurors.*
S3.2	I didn't pay attention to that.	
S3.3	I couldn't monitor who looked and who did not, but I remember seeing that they acted to look.	

Table F.14 (continued) : Excerpts from the students' responses to the second question in Table 5.20.

Juror or Student	Excerpts from the transcription of interview records	Annotation by the researcher
S4.1	I guess they didn't look at.	*The VR scene of Group 4 was experienced by three jurors.*
S4.2	I think that not every juror looked at.	
S5.1	I guess all jurors except for one looked at. I'm not sure.	*The VR scene of Group 5 was experienced by three jurors.*
S5.3	I'm not sure who wore it or not, but I think they all did.	
S6.1	Yes, they all did.	*The VR scene of Group 6 was experienced by three jurors.*
S6.2	I think they looked, but Juror 1 did not.	
S6.1	No, Juror 1 looked as well. I remember that day. S/he looked as well.	
S6.3	The jury on the left looked, right? I don't remember that the one on the right looked.	
S7.2	I think they looked.	*The VR scene of Group 7 was experienced by all jurors.*
S7.1	I think Juror 1 looked.	
S8.1	I don't know. I did not see. I think they did not look.	*The VR scene of Group 8 was experienced by all jurors.*
S8.2	I guess one or two jurors looked, but I'm not sure.	
S8.3	I think two jurors looked.	
S9.1	No. I remember they didn't look.	*The VR scene of Group 9 was experienced by one jurors.*
S9.2	I remember that they looked.	
S10.1	I guess they looked.	*The VR scene of Group 10 was experienced by two jurors.*
S10.2	Juror 4 and 5 looked.	

Table F.15 : Excerpts from the responses to the fifth question in Table 5.20.

Juror or Student	Excerpts from the transcription of interview records
J1	It was interesting. A student was talking about their design decisions and the reasons behind them by walking around in something that was not really there and by pointing out some things there. This is very valuable information. It is a kind of information that we cannot get from the sheets.
J2	It was better than the others.
J4	It was very effective for presenting the product. It had a positive effect and gave us a better understanding of the product.
J5	Looking at images that move with someone else's perspective gives me the feeling that my freedom to look wherever I want is restricted. Also, the current speeds of the processors are not yet capable of producing images that can replace the real image. Therefore, I think the details I can capture from a high-quality rendered image are more than what I can capture from a constantly moving camera.
S1.1	It was very good.
S1.2	It's nice to be able to explain by entering it. But it's hard to tell without eye contact.

Table F.15 (continued) : Excerpts from the responses to the fifth question in Table 5.20.

Juror or Student	Excerpts from the transcription of interview records
S2.1	They may not be looking at the things on the sheet while I am explaining them. But everything is clear and understandable in VR.
S2.2	It was very good. Because you are showing what you are telling about. Besides, nobody gets distracted.
S3.1	I think it was a good presentation. I think it was a great convenience to show and explain.
S3.2	I think it was explanatory.
S3.3	Actually, it is advantageous. I think it is an advantageous situation for students. Because you can focus on the points whatever you want, and show them directly from your own point of view.
S4.1	Logical. In this way, the rest of the class can see it.
S5.1	Yes, it's a good technique.
S6.2	I think to make practice is needed to make such a presentation.
S6.3	Frankly, I think this is a more useful method.
S8.1	I found it logical.
S10.1	It was good.

Table F.16 : Excerpts related to the jurors VR equipment preferences.

Juror or Student	Excerpts from the transcription of interview records
J1	It was necessary to stand up to use the HTC Vive. Therefore, in order not to break the jury process, I preferred the handier one that allows me to be able to look at the VR scenes without leaving my chair.
J2	I didn't need it. Why would I need it when the mobile VR glasses were in front of me? On the other hand, it was as if it belonged to the students. I mean, I thought I would watch while one of the students was giving a presentation by using it.
J4	To use the HTC Vive, it is necessary to leave the jury table and stop the jury process. There is also a time limit, and entering the VR environment and experiencing the VR scenes by using the HTC Vive causes to exceed this time. If mobile VR glasses had never been on the table, the HTC Vive could have been used for a better understanding of some points. But, the presence of mobile VR glasses made it unnecessary.
J5	Since we had a negative experience with the use of HTC Vive in the previous jury session and we discovered the practicality of using mobile VR glasses, I chose this option. I think it is more suitable for our needs.

Table F.17 : Excerpts related to whether the shared use of mobile VR equipment caused any trouble.

Juror or Student	Excerpts from the transcription of interview records
J1	No, it didn't. Two were sufficient. Even only one can work.
J2	There was one pair of VR glasses per two jurors, but even that was sufficient. It was as if each juror has one pair of mobile VR glasses.

Table F.17 (continued) : Excerpts related to whether the shared use of mobile VR equipment caused any trouble.

Juror or Student	Excerpts from the transcription of interview records
J4	Theoretically, it would be better to have one per jurors. Eventually, we share an object that touches our skins.
J5	Having one pair of mobile VR glasses for each jury member would, of course, be more advantageous in terms of freedom of use. But I don't think it would make a big difference for me.

Table F.18 : Excerpts related to why the jurors needed to experience the VR scenes in this jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	Once again, I observed that the students could not explain their projects with only the help of sheets. I looked at the VR scenes as soon as I felt that the narrative was insufficient.
J2	Actually, I wanted to experience and understand the subjects that the student could not explain or fully explain verbally. Because there were some mistakes on the sheets or there sometimes were things they don't mention. In other words, some things couldn't express correctly.
J4 **J5**	To understand things that couldn't be explained with the sheets, to check or verify whether I accurately understood the things I saw on the sheets, or the things told by students.

Table F.19 : Excerpts related to demands for the next jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	In the first two minutes and three minutes, I want that students make a presentation with the Htc Vive as Group 7 did, and then explain the other details on the sheets. And I would also like that there will be mobile VR glasses that jurors can use whenever they want. On the other hand, I observed that the students were not very successful at arranging the renderings of a large product on A3 size sheets. The drawings and renderings on the sheets were too small to see clearly. Therefore, I also would like that the sheets are projected onto a big screen. However, it is also important to see the sheets together in order to comprehend the whole. It would be great if all these conditions are established.
J2	I would like that while one student was making a presentation over the sheets, the other was showing the details s/he told about on the big screen by walking around in the virtual model. If it's really not enough for me, I should use the mobile VR glasses.
J4	The use of mobile VR glasses should continue. Jurors should not have to evaluate the projects by looking at small sheets.
J5	It will be good if there are revolving (swivel) chairs for the jurors… Having one pair of mobile VR glasses per two jurors will be sufficient.
S1.1	It seemed to me that the presentations would take a long time if they were made as Group 7 did. But it was actually a good presentation. We can also make such a presentation. Because the sheets are very small because they are in A3 size.
S2.2	We, as well, should make a presentation like that *(refers to the presentation of Group 7)*. That was very good.

Table F.19 (continued) : Excerpts related to demands for the next jury session.

Juror or Student	Excerpts from the transcription of interview records
S2.3	While the presentation is going on, one of us can show what is being mentioned in the VR environment.
S3.1	I think we should make a presentation as Group 7 did.
S3.2	I agree. But I would like the jury members to also experience it.
S3.3	While two of the group members are continuing the presentation, the other can show what is being mentioned in the VR environment.
S4.1	I think it should be like that *(refers to the presentation of Group 7)*.
S4.2	I agree. In this way, everyone is focused on the presentation at that moment.
S5.1	I think Group 7's presentation technique was very good. That's enough.
S5.2	I find it coherent for the jury members to experience our VR scene after we explain our design by showing it in the VR environment.
S5.3	I think it would be effective to present our design as Group 7 did. But I would like the jurors to evaluate our design after experiencing it with their VR glasses.
S6.3	Yes, I think presenting like that *(refers to the presentation of Group 7)* is very useful. Thus, the projects can be explained more clearly.
S7.1	I think this *[jury]* setup was a good setup. The next one should be the same.
S8.1	I think it would make it more logical if one of us uses VR during the jury session to show what the others were talking about at that moment.
S8.2	It would be more effective for us if the jury members can make their comments by showing the things, which they are commenting on at that moment, both on the sheets and on the image projected from the VR scene to the wall.
S9.2	That *(refers to the presentation of Group 7)* was very good.
S10.1	I would like to see which one is looking at where in our VR scene while the jury members use their mobile VR glasses.

3. Excerpts from the third-round interviews

Table F.20 : Excerpts related to the comparison of the proposed ways of VR use in the final jury session and the previous one.

Juror or Student	Excerpts from the transcription of interview records
J1	This time, there was no distraction, disruption, etc.[...] Because all kinds of comfort were offered to us. The HTC Vive setup for design presentations and its VR screen projected on a board, the mobile VR glasses for experiencing the VR scenes, digital and non-digital design sheets, and 1/10 scale physical models enabled students to explain all aspects of their projects. In other words, complementary information was available side by side and seamlessly. So, I didn't think there was any problem.
J2	I think the last one was very good.
J3	It was much better for the students to enter the VR environment and explain their project according to their own orders and that we could watch them on the projected screen.
J4	The way of VR use in the final jury setup was the best. Presenting the projects by the students in the VR environment through the projected screen was much better.

Table F.20 (continued) : Excerpts related to the comparison of the proposed ways of VR use in the final jury session and the previous one.

Juror or Student	Excerpts from the transcription of interview records
S1.1	In the last one, I believe we were able to explain everything that we thought we had to explain. Nothing was left as missing. It was very useful.
S1.2	We generally have too much anxiety about explaining our projects in the juries. We are very worried about whether we can explain it correctly and whether our project will be understood correctly. The last jury setup has eliminated all of them. It was relaxing, and it made me happy.
S1.3	There was a very well-planned and smooth system in the final jury session. It was very effective. It provided a full evaluation of the project.
S2.1	The last one was very useful. It made our project easier to understand.
S2.2	Unlike the previous ones, we had a more efficient jury process in terms of VR use. I think it was a successful setup and helped us present our project in the best possible way.
S3.1	I think that the way of VR use in the previous jury session was more effective.
S3.2	In the final jury session, I wore the VR glasses and S3.1 explained our project via the sheets. This experience made me think that it is still a deficiency that the person wearing the glasses could not see the sheets. Apart from this, I think using VR in this way is especially good for explaining the project.
S3.3	Compared to the previous jury sessions, I believe the use of VR was much more efficient in the final jury session. The jury process proceeded in a planned and very practical way in itself.
S4.1	The last one was fast and fit its purpose perfectly. It was easier for us to show the details. And also, it became easier to understand the details. We were able to explain the dimensions of the product better by referencing ourselves. It was so successful. Only, the VR presentation area was a little small.
S4.2	The use way of VR in the final jury session was much more comfortable than the previous ones.
S4.3	The last one was highly fluent and smooth.
S5.2	The last one was so good.
S5.3	The last one was quite enough. I liked it very much.
S5.1	I agree.
S6.2	The last one was the most mature version.
S6.3	I liked the last one very much. It was very comfortable, and the system was well-established.
S6.1	I agree. The last one was better.
S7.1	The last one was good. It even felt like I was doing a professional job. Only, the VR presentation area was a little small. It would be better if the VR presentation area was a little bigger.
S7.2	I think the last one was very good and well-integrated.
S7.3	I agree.
S8.2	The way of VR use in the final jury session was very successful, compared to the previous ones. It was very comfortable. So I think it was good.
S8.3	I agree.

Table F.20 (continued) : Excerpts related to the comparison of the proposed ways of VR use in the final jury session and the previous one.

Juror or Student	Excerpts from the transcription of interview records
S8.1	I agree. I also think the jury setup layout as well was very good.
S9.1	In the last jury session, I think we used VR technology quickly and comfortably enough.
S9.2	I agree.
S10.1	I think, we've used VR in all jury sessions so far, but the last one was the most effective.
S10.2	We explained our project very comfortably in the final jury session.

Table F.21 : Excerpts related to whether VR was well integrated into the jury practice in the final jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	Yes, it was. It even became an essential part of it.
J2	Yes, it was. It was progressed and adapted step-by-step. Each time I felt like this was the best, but I saw it got better with revisions one step later.
J3	I think VR technology was able to be integrated into the jury practice and very useful.
S1.1	I think it was very well integrated.
S1.2	I agree.
S1.3	I agree.
S2.2	Yes, it was.
S3.2	I think it was not able to be integrated completely. So, in my opinion, there were still some setbacks.
S3.3	I think it was well integrated.
S3.1	I think it was better integrated into the jury practice in the previous jury session.
S4.1	Yes, it was.
S4.2	I agree.
S4.3	I agree.
S5.1	In the end (in the final jury session), I think it was well integrated.
S5.2	I agree. It was very efficient in the final jury session.
S5.3	I agree.
S6.3	Yes, it was.
S6.2	I agree.
S7.2	Yes, it was.
S7.3	I agree. It even became the main component of it, I think.
S7.1	Exactly.
S8.2	Yes, it was. Actually, this was what we had in mind. Even, it was much more integrated than I expected. I cannot imagine beyond this taking into consideration the current maturity level of technology.

Table F.21 (continued) : Excerpts related to whether VR was well integrated into the jury practice in the final jury session.

Juror or Student	Excerpts from the transcription of interview records
S8.1	I agree.
S8.3	I agree.
S9.1	Yes, it was.
S9.2	I agree.
S10.1	Exactly, it was.
S10.2	I agree. It was really well integrated into the final jury session.

Table F.22 : Excerpts related to the use of physical models and mock-ups in the final jury session.

Juror or Student	Excerpts from the transcription of interview records
J1	The physical model also told us some things. We, fortunately, asked them to make a 1/10 scale model.
J2	I looked at the physical models as well, but I want to confess that I didn't really need the models and sheets. I constantly looked at the VR scenes.
J3	Frankly, I think physical models are very useful for us as well as for students in terms of envisaging the links between design ideas and the real world.
J4	I think there was no need for 1/10 scale models.
J5	I think that the physical models, except for 1/1 mock-ups, did not contribute much to the narration of the projects.
S1.1	It was unnecessary because VR was used.
S1.2	We spent a lot of time making the physical model. But, it was not used effectively.
S1.3	Since VR was used, the physical model was very useless. It was not even looked at.
S2.1	I do not think the 1/10 scale model was examined in detail.
S2.2	They did not draw attention and were not examined in detail. That's why I found them unnecessary.
S3.1	If there is a physical model, it should not be VR there.
S3.2	The physical models we made attracted less attention compared to VR.
S3.3	Frankly, I had thought that the use of VR would eliminate the need for physical models at the beginning of the project process, and the final jury made me sure of this thought.
S4.1	I felt that if there is VR, the physical model loses its importance.
S4.2	Normally, they attach great importance to our physical models. They take them in their hands and look at them one by one. They examine them in detail. However, this time, nobody looked at them.
S4.3	I think the physical model was so unnecessary that none of the jurors even looked at it.
S5.2	The physical model was nice to perceive the design in 3D, but I am not sure if it is necessary indeed when VR is used.
S5.3	Yes, we made a 1/10 scale model. But I don't know what and how much we were able to explain with that model.

Table F.22 (continued) : Excerpts related to the use of physical models and mock-ups in the final jury session.

Juror or Student	Excerpts from the transcription of interview records
S5.1	Even if it is 1/1 scale, a physical model is something that is made by hand. And it doesn't actually be made perfectly. It has always more or less defect. But if your virtual model is good, you can make your presentation much more comfortably by using it.
S6.1	The necessary attention was not paid to the physical models.
S6.2	It was so unnecessary.
S6.3	It has not even been looked at.
S7.1	I observed that the physical models were not looked at so much.
S7.3	The 1/10 scale model was unnecessary.
S7.2	I agree. It was unnecessary.
S8.3	The 1/10 scale model was so unnecessary. However, the 1/1 scale mock-up was very useful.
S8.2	I think there is no need to make a 1/10 scale model if VR is being used there.
S8.1	The 1/10 scale model was an extra and unnecessary workload for us.
S9.1	I think the physical models were omitted a little.
S9.2	Physical models were scarcely ever looked at.
S10.1	The model was functional for presenting the exterior of the vehicle. But it was unnecessary for presenting the details inside.
S10.2	We spent a lot of time making the 1/10 scale model. But it was not used.

Table F.23 : Excerpts related to whether being wondered what a juror saw and/or where s/he looked in a VR scene while s/he was experiencing it by using the mobile VR glasses.

Juror or Student	Excerpts from the transcription of interview records
S1.1	Yes, I did. I actually wondered whether they experienced our VR scene as we experienced it with the HTC Vive.
S1.2	I wondered which details of our design were examined by the jurors.
S2.2	Yes, we did. Because we couldn't see.
S4.2	I did. Because S4.1 has already told by showing. I was very curious about what's the extra there. I wondered what was there different from what we showed.
S4.1	I wondered if they could experience the mobile version of our VR scene just as I experienced it with the HTC Vive.
S5.2	I wondered if they could navigate within the VR scene with their mobile VR glasses. I wondered whether they were able to examine all parts of our design.
S7.3	Yes, I did. Because they looked at our VR scene, and then took notes. So, I was very curious about what they thought when they experienced our VR scene.
S8.3	I did. Because there were some details in our design that were not well resolved, and we didn't want them to see these details. But we couldn't see whether they looked at these details. I hope they haven't looked at those parts.

Table F.23 (continued) : Excerpts related to whether being wondered what a juror saw and/or where s/he looked in a VR scene while s/he was experiencing it by using the mobile VR glasses.

Juror or Student	Excerpts from the transcription of interview records
S9.1	I did not. Because they were giving feedback by commenting or asking questions. It was already clear from their comments and questions where they looked in the VR scene.
S10.1	I did not wonder this time. Since they focused on what we showed during the presentation, I was not curious so much about where they looked after the presentation.

CURRICULUM VITAE

Name Surname : Ahmet Hamurcu

EDUCATION:

- **B.Sc.** , 2008, METU, Faculty of Architecture, Industrial Design Department
- **M.Sc.** , 2014, ITU, Graduate School of Science Engineering and Technology, Industrial Product Design Programme
  "Türkiye'de kullanıcı deneyimi pratiği ile endüstriyel tasarımcıların ilişkisi üzerine bir araştırma"
  Advisor: Assoc. Prof. Dr. Şebnem Timur Öğüt (ITU)
  Co-advisor: Asst. Prof. Dr. Ali Emre Berkman (TOBB-ETU)

PROFESSIONAL EXPERIENCE AND REWARDS:

- 2012-2021 ITU Industrial Product Design Dept. / Res.Asst.
- 2011-2012 Amasya University, Faculty of Architecture / Res.Asst.
- 2011-2011 Bürotime Office Furniture / Designer
- 2009-2010 Kırıkkale University / Instructor (Part-time)
- 2008-2009 Tamer Industrial Project / Designer
- 2006-2007 INTA SpaceTurk / Project Staff
- 2018 Top 8 papers among ESRs award, Green Lines Institute for Sustainable Development, Portugal.

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Hamurcu, A.**, Timur, Ş., & Rizvanoglu, K. (2020). An overview of virtual reality within industrial design education. *Journal of Engineering. Design and Technology*, 18(6), 1889-1905. DOI: 10.1108/JEDT-02-2020-0048
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- Ulubaş Hamurcu. A., & **Hamurcu, A.** (2018). An evaluation of the use of reality technologies in conservation of cultural heritage. In *HERITAGE 2018 - 6th International Conference on Heritage and Sustainable Development*, 2, 1355-1362.

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CERTIFICATES:

- Usability and User Experience Certificate Program, Kadir Has University Lifelong Learning Academy, Istanbul. (02.11.2013 – 11.01.2014)
- Individual Usability and User Experience Design Training, Userspots, Istanbul. (26-28 September 2013)

AREAS OF INTEREST:

Industrial Design, Product Design, Research Methods, User Research, Usability, User Experience, Reality Technologies (VR/AR/MR)

COURSES ASSISTED IN LAST 5 YEARS (ITU):

2020-2021 Spring	Industrial Design Studio III Computer Aided 3D Modeling
2020-2021 Fall	Industrial Design Studio II Culture and Communication in Product Design
2019-2020 Spring	Industrial Design Studio III - IV Computer Aided 3D Modeling
2019-2020 Fall	Industrial Design Studio I Model Making I
2018-2019 Spring	Industrial Design Studio II - III Computer Aided 3D Modeling Graduation Project
2018-2019 Fall	Industrial Product Design III Computer Aided Design
2017-2018 Spring	Industrial Product Design III Computer Aided 3D Modeling
2017-2018 Fall	Industrial Product Design IV-V Computer Aided Design
2016-2017 Spring	Project III Computer Aided 3D Modeling
2016-2017 Fall	Industrial Product Design II - III Computer Aided Design

COURSES GIVEN AS PART-TIME INSTRUCTOR:

2009-2010 Spring	Ergonomics	Kırıkkale University
2009-2010 Spring	Computer-II	Kırıkkale University