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Constructivist Digital Design Studio with Extended Reality for Effective Design Pedagogy

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Abstract

It is evident from previous research that learner preference, cognitive load and effective learning are interconnected. Designers' individual characteristics and preferred modality of information delivery in the design studio has direct relation to the effective use of the information delivered. This study evaluates and discusses possibilities of using XR (Extended Reality) technology within the framework of constructivist learning approach in the interior design studio by measuring its effectiveness as a pedagogical tool. The nature of the design studio and its pedagogy stayed nearly analogous throughout the past century (Bashier, 2014; Koch, 2006). The exponential advancement of information, communication technologies and generation Z's assertiveness toward electronic 'device' oriented lifestyle are the two major challenges that today's design studios yet to adopt for effective design education. With an overview of contemporary design pedagogy and the potential use of XR for a constructivist learning environment; this study explores students' learning styles and identifies how these learning preferences affect their learning outcome in traditional and Extended Reality based learning environment.

Keywords

design studio instructions; traditional method; extended reality; learning styles; learning outcome

Introduction

Design education in this digital age is facing major challenges to bridge the gap between conventional design education and generation Z's learning preferences. This is due to the unimaginable pace of advancement of technology and its recent shift from the *Information Age* to *Experience Age* (Wadhera, 2016). Designers are unique in their creative thinking and ideation process, synthesizing information, constructing new knowledge and are explicitly influenced by gender, culture, background, cognitive style, available technology and exposure to the outside world (Baer, 1997; Baer & Kaufman, 2008; Gül, Gu, & Maher, 2008; Hu-Au & Lee, 2017; Lubart, 1999; Pearsall, Ellis, & Evans, 2008; Shalley, Zhou, & Oldham, 2004; Wolfradt & Pretz, 2001). Previous researches have shown that efficient use of design modality and its interface is dependent on the user preferences; therefore strongly contributes to effective learning. Effective learning in a design studio largely relies on the effective communication of design ideas and the relationship among learners' preferences and instruction modality (Demirbaş & Demirkan, 2003). In general, design pedagogy is founded on Euclidean understanding of form and space that teaches "descriptive geometry" (Lee & Reekie, 1945), theory and application of artifacts to occupy and involve human activity. But the advancement and inclusivity of technologies in all aspects of generation Z's '*device*' oriented lifestyle presents new challenges for design education. Constructivist teaching and learning method is often considered to be one of the techniques that integrate different pedagogy and epistemological methods in education. Enough studies are not available that explored the potential of teaching in design students using Extended Reality platform within the framework of constructivist learning. Extended Reality is relatively new platform that incorporates characteristics of VR (Virtual Reality), AR (Augmented Reality) and Mixed Reality (MR). VR is an immersive, simulated three-dimensional environment (Bryson, 1995), AR overlays digital (augmented) geometry in the physical environment where the task is performed (Fischer, Bartz, & Strasser, 2005) and MR anchors digital contents in the real world where users can perceive both physical and digital objects simultaneously.

The purpose of this study is to explore how learner preferences affect the use of traditional and Extended Reality-based information delivery method for constructivist learning in the design studio. Several studies investigated the process and implications of virtual environments in design communication and presentation; however, a vacuum exists in knowledge regarding how technology-based information delivery method affect the cognitive process of learning in a constructivist design studio. A modified technology acceptance model (TAM) questionnaire (Fred D. Davis, 1989, 1993; Viswanath Venkatesh & Davis, 2000) was used along with the VARK learning styles tool to measure learner preferences (learning styles) as visual, auditory, read/write, and kinaesthetic. A number of researchers (Bell, Koch, & Green, 2014; Drago & Wagner, 2004; Lau, Yuen, & Chan, 2015) have advocated for the validity of VARK as a learner preference measuring instrument.

The rationale in this study is- design students, who are mostly visual and kinaesthetic learner will prefer to use an information delivery method that delivers a higher level of tactility and visual cues, therefore, it will decrease cognitive load and increase intrinsic motivation to construct a meaning resulting effective learning.

Learner's preference over learning style and the use of modalities as a mean to learn have influence over the learning effectiveness. It also influences the way one constructs meaning, represents experience, relates to reflections and effectively applies acquired knowledge. The primary hypothesis of this study is that learners' preference has a correlation with the acceptance of certain means of information delivery method or technique, therefore it affects the learning effectiveness through lowering cognitive load and intrinsic motivation that commonly visible in constructive learning and teaching methods (Figure 1).

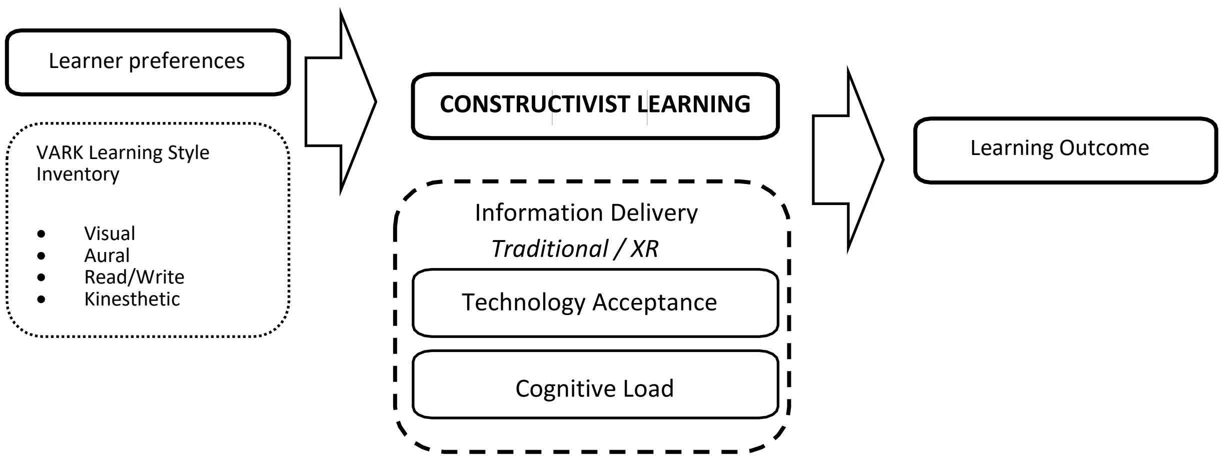

FIGURE 1. THE EFFECT OF LEARNER PREFERENCES ON LEARNING OUTCOME IN CONSTRUCTIVIST LEARNING APPROACH

Current State of Design Education and its Realignment

Concerns regarding design education and its alignment with today's digital age, generation Z students' learning preference, and fast-changing needs of the industry are not new. In one form or another, similar issues have emerged in the early restructuring efforts of 1960s experimental college by John Dewey, Alfred Whitehead, Jean Piaget, Benjamin Bloom and more recently David Kolb (Salama, 2006). Fisher (2000) mentioned, "Studio culture pedagogy originates, in part, from 18th century and 19th century French rationalism, which held that through the analysis of precedent and the application of reason, we could arrive at a consensus about the truth in a given situation". Originated from the Ecole des Beaux-Arts, this approach of design learning and teaching was adopted by the Western schools of architecture and then spread around the world. It was emerged around the seventeenth century in France to represent the authoritative needs at that time and lasted for over two hundred years as the only model for design education. Due to the change of the value system caused by technological development and industrial revolution, an alternative approach emerged at the end of the nineteenth century in Germany called the Bauhaus model. Most of the design schools around the world are highly influenced by Beaux-Arts and Bauhaus models and still follow the same principles. These approaches of design pedagogy created a distance from the real world because of the lake of opportunities it provides to learn from the 'richness and depth of human experience' (A. Salama & Wilkinson, 2007).

In recent decades, technology has faced several major shifts which also influenced the lifestyle and learning preferences of design students of today's digital age. The most recent shift from the Information Age to the Experience Age brought a major challenge for design educators (Hu-Au & Lee, 2017; Wadhera, 2016). Since the act of design is an individualistic, creative and diverse domain grounded on non-linear thinking and problem-solving process where rationale emerges from individual designer's level of experience, reflections and perceptions. Therefore, an exploratory, constructive learning environment can improve the motivation, attention and overall learning outcome (Clark, D. 2006 in Piovesan, Passerino, & Pereira, 2012). Virtual, Immersive and augmented learning environments provide unique contextual role-playing and reasoning experience where early design students learn the essential skills as creative thinking, empathy, conceptual understanding, system thinking and such through learning by doing. This also provides design students of this digital age necessary active engagement (Capps & Crawford, 2013) and relevance of the learning material to their professional life (Gee, 2009).

Extended Reality as Constructivist Learning Environment for Design Education:

Extended Reality (XR) is the umbrella platform that encompasses phenomena from Virtual Reality, Augmented Reality and Mixed Reality. By definition, it incorporates real and virtual environment and relevant interactions between human and computers. The goal is to offer feedback based experiences mainly involving the senses of existence, confirming cognition and interaction with contextual geometry and design elements. Digital modalities can facilitate human memory and learning by refining mental models, adding interpretations and providing experience by augmenting the real world (Perkins, 1992). Virtual, Augmented and Mixed Reality technologies have proven its potential by providing a constructivist learning environment that creates a natural and social interactive platform to mediate interaction with the contents (Dede, 1995).

In constructivist learning theory, learners construct knowledge and meaning from experience, active participation and performing tasks in the context which allow learners to contextualize the process of constructing knowledge instead of being a passive learner (Salomon & Perkins, 1998). With various methods constructivist learning allows students to get engaged based on his or her specific character, talent and preference; therefore, it is considered as a useful method to disseminate information in design studios (Jones & Brader-Araje, 2002; Naylor & Keogh, 1999; Rovai, 2004; Soygenis, 2009).

Learners make a tentative interpretation of experience, elaborate and test those interpretations based on their reflections until a mental structure is formed and satisfactory structure emerges. The learning environment and information delivery method need to be supportive of the development of this inherent constructivist character. By facilitating human memory and intelligence extended reality based digital modalities create constructivist learning platform and offer multiple interpretations, mental models and experience of built environment (Dede, Salzman, & Loftin., 1996; Perkins, 1991). Constructivist digital studio incorporates innovative approaches (Gül et al., 2007) as experience-based “new ways of designing” (Kvan & Jia, 2005) by integrating the Extended Reality (XR) technology and design thinking (Gül, Gu, & Williams, 2008; Kvan & Jia, 2005).

Constructivist Learning Environment that Promotes Experience using Extended Reality:

As discussed in the previous section- since Bauhaus experiments of the 1930s, alternative approaches for design education received increasing attention among design researchers (Gül et al., 2008) as “Reflective Practitioner” philosophy Donald Schon (1987), “Problem-Based Learning” by Donald Wood (1994). By integrating diversity in knowledge, skills, culture and problem-solving ability to satisfy ‘real-world’ needs, Woods (1994) formed experiential learning approach that essentially is based on reflection. In traditional model of education, instructors deliver information to the students following ‘one size fits all’ method that appears to be outdated and increasingly unsuccessful (Hu-Au & Lee, 2018; Wadhera, 2016). This is due to the shift of Industrial Revolution model of education to an Information Age model where information accumulation was in highest priority and now in the Experience Age where information is constructed through experience and ‘on demand’. It is evident in generation Z design students’ lifestyle where the ubiquity of interconnected mobile devices, cloud-based large data, gaming and social networking application, various machine learning and artificial intelligence support have altered the expectation and understanding of information sharing and experiencing new points of view.

Use of emerging technologies and new information is the fundamental approach of the constructivist learning approach of design. Constructivism demonstrates methods of constructing his/her own understanding and knowledge about the world around them by experiencing elements and reflecting on those experiences (Mahoney, 2004). Using an active and interactive learning process knowledge is obtained and synthesized by active (re)constructions of learner’s mental frameworks (Abbott & Ryan, 1999; Brown, Donovan, & Pellegrino., 2000).

Extended Reality has tremendous potential to be used as an information delivery tool for any constructivist learning environment since it encompasses the characteristics of VR, AR and MR. Virtual Reality and Augmented Reality technologies are widely being used in design education and industry but mostly for presentation purposes. VR is considered as an immersive computer-generated and simulated three-dimensional environment while AR superimposes virtual geometry over the physical environment.

Extended Reality is much flexible and completely immerses its user inside a computer-generated environment where the user may or may not relate to the physical environment, but can interact, receive feedback, forwarded to secondary sources for further information and such. Like AR interface XR (Extended Reality) offers tangible interaction (Ishii, 2007) which might be useful to the kinesthetic learner while visual learner benefits from VR. A void exists in knowledge about these several decades old technologies' effect on human factors (Huang, Alem, & Livingston, 2012), acceptance of technology (Fred D. Davis, 1993; Dishaw & Strong, 1999; Igbaria, 1993) and measured cognitive load (Mohamed-Ahmed, Bonnardel, Côté, & Tremblay, 2013) that potentially contributes to the intrinsic motivation to learn and construct new knowledge resulting effective learning in design studios. Therefore, a comprehensive understanding of user experience factors in this virtual and augmented environment is essential to verify its usability as a pedagogical tool for constructivist design studio. At the same time this understanding will help with experimenting, developing and introducing such new technologies into mainstream design pedagogy to support generation Z's learning style and preferences.

User Preferences on Design Learning

Most of the discussions, instructions and explorations in the design studio utilize digital modalities of various kind. Individuals (re)act differently with different digital interfaces because of their background, exposure, aptitude with the technology in use as well as the intrinsic quality of the tools they are using. One of the goals of this study is to explore user preference of digital interface for learning design ideas. Constructivist learning theory highlights the human-centered approach. Most researches in design education using digital media have focused on the use, development and technical aspect of it. A few studies exist on the human center approach (Gabbard & Swan II, 2008) and experience-oriented aspect of design learning approach. It is essential to understand the relation between user preference and system's characteristics because in extended reality technology both physical and virtual objects create the environment in combination (Grier et al., 2012).

It is crucial for designers to effectively communicate complex design solutions which require intellectual comprehension of a given design problem and ability to synthesize, manipulate and construct a mental image of the solution beforehand (Isham, 1997). Since the act of design is highly subjective so as the designer's cognitive ability, thinking process, innate skills, intelligence and preferred learning method. Gardner (2011) developed multiple intelligence theory and identified seven types of intelligence among designer as logical, kinesthetic, spatial, interpersonal, intrapersonal, verbal, and musical. He mentioned individual success in any specific sector is dependent on the selection of the appropriate and preferred method of education, in other word information delivery method that foster this intelligence. According to Thurstone (1938), factors as associative memory, perceptual speed, reasoning, spatial visualization, word fluency and verbal comprehension work in combination to define intelligence. Among these, mental rotation, spatial visualization, and spatial perception characterize one's ability for spatial perception.

Constructivist learning and teaching emphasize on learner-oriented teaching method that does not follow 'one size fit all' approach. Therefore, it is important to understand the idea of learning styles because each individual has a preferred method of learning that suits them the most. This study focuses on identifying individual learner's preference of instructional modality for delivering information in design studio (i.e., through the Traditional or XR interface).

Learner Preferences in Design Education

Learning styles or preferences in design describes the different patterns of how designers learn and solve problems (James & Gardner, 1995). A number of classifications developed by researchers on how individuals learn; for example, Keefe (1979, p. 2) defined it as "cognitive, affective, and physiological traits that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment". Personality learning, information processing, social learning, and multidimensional instructional learning are considered as four major learning theories which were identified by Curry (1983). The common denominators among all these theoretical frameworks are the personality, information processing and interaction with the environment (Kolb, 1984). While describing learning, Gardner (1983) mentioned a number of dimensions of learning as interpersonal, intrapersonal, visual-spatial, bodily-kinesthetic, linguistic, and logical. This study attempted to understand design students' learning styles by identifying their preference for different types of information delivery methods (traditional and XR based) and perceived efficiency of that interface for effective learning in design studio.

Through observation and exploration of design students' learning preferences design educators tried to identify a connection between teaching and learning in the design studio (Demirbaş & Demirkan, 2003; Kvan & Jia, 2005; Newland, Powell, & Creed, 1987) as well as cognitive styles (Newman, 1981). Generally learning preferences varies between learners from different disciplines of education (Felder, 1988). Students from certain disciplines may show some similarities in learning preferences due to shared interests and comparable aptitude (Felder, 1988; Lujan & DiCarlo, 2006). Design education is heavily dependent on visuals, survey of physical environment, demonstrative activities and such which dictate certain learning preferences. Successful problem solving rely on (self) reflection (Schon, 1987) where designers revisit and reflect on design thinking based on their previous experience and exposure (Newland et al., 1987). Designers acquire these experiences and exposures over time; however, constructing meaning from observation require different level of cognitive ability. Therefore, information and instruction delivery methods that reduce cognitive load and promote motivation and acceptance among learners are likely to positively affect meaningful learning.

Constructivist Learning, Experience, Motivation and Acceptance:

Alternative approaches for design pedagogy received more attention among design educators since the Bauhaus experiments of the 1930s (Gül et al., 2008). In constructivist learning, emerging technologies and new information play a fundamental role. Reflection is one of the most valuable instruments of a designer which is essentially based on diversity in knowledge, skills, culture and problem-solving ability to satisfy ‘real-world’ needs. Due to the differences in cognitive ability successful mental construct occurs when information is delivered using preferred method that motivates the learner. Personal determination to accomplish something is generally considered as motivation which can be intrinsic or extrinsic. Accomplishing a job for one’s own satisfaction is intrinsic motivation while finishing a task without any determination and only it means to an end approach is defined as extrinsic motivation (Amabile & Gryskiewicz, 1989). In the context of design learning, when intrinsic motivation is less creativity, output and learning effectiveness decreases (Casakin & Kreitler, 2009; Collins & Amabile, 1999; Kreitler & Casakin, 2009).

Within TAM (technology acceptance model), perceived usefulness (PU) defines "the degree to which a person believes that using a particular system would enhance his or her quality and performance" while perceived ease of use (PEU) defines "the degree to which a person believes that using a particular system would be free from effort" and considered as an important determinant for user acceptance (Fred D. Davis, 1989). Intrinsic motivation for using technology and mechanism can be captured and constructed by utilizing the technology acceptance model (TAM) (Fred D. Davis, 1989, 1993; Viswanath Venkatesh & Davis, 2000). Intrinsic motivation to learn and effectively use any instruction or delivered information is related to perceived ease of use as considered by its user (Viswanath Venkatesh, 2000). These two perceived variables influence learner’s attitudes toward effectively using technology and the behavioral intention to use (BIU) technology for future activities. If learner is motivated to use the technology that promotes constructivist learning through active participation and interaction then effective learning can occur. Technology acceptance is related to perceived ease of use (PU) and perceived ease of use is affected by intrinsic motivation; therefore intrinsic motivation is very likely to be affected by technology acceptance (Figure 2).

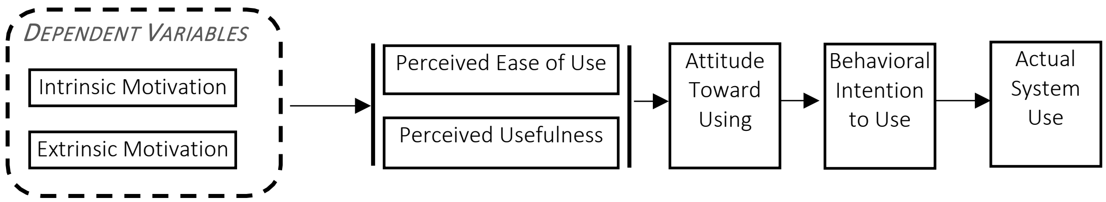

Figure 2: Motivation on the technology acceptance (TAM).

Perceived ease of use demonstrates the ability to maneuver a wide range of computer applications for various purposes (Schiller, 2003). In the context of this study, perceived ease of use reflects design students' degree of expectation over the information delivery system be free from effort and require less cognitive load (Fred D. Davis, 1989). Perceived ease of use also refers to the intrinsic motivation which enhances learning outcome. This study examined whether perceived ease of use is related to learning using this connection. In the traditional method of instruction in design studio does not offer enough opportunity for kinesthetic learners which can be optimized using the tangibility of digital user interfaces in the context of the specific built environment. According to Gee (2009), students struggle to find relevance to their real-life activity when information is delivered out of context. In the traditional method of information delivery creating a scenario of realistic context is difficult and require either higher level if cognitive involvement or experience form learners. Virtual environments can be considered as an extension of traditional design pedagogy to motivate visual, kinesthetic or aural learners. Moreover, generation Z learners need to develop some crucial skills as creativity, empathy, integrated design and system thinking, abstract reasoning which are difficult to teach (Smith and Hu, 2013) and to some extent is ignored in the traditional method of design learning and teaching (Hu-Au & Lee, 2018). Within the framework of constructivist design pedagogy, this study investigated learners' preference over the use of traditional and XR based information delivery method. Learner's preference affects motivation (Anasol, Ferreyra-Olivares, & Alejandra, 2013) to learn and actively participate. Therefore, preference of instructional method will affect effective learning (figure 3).

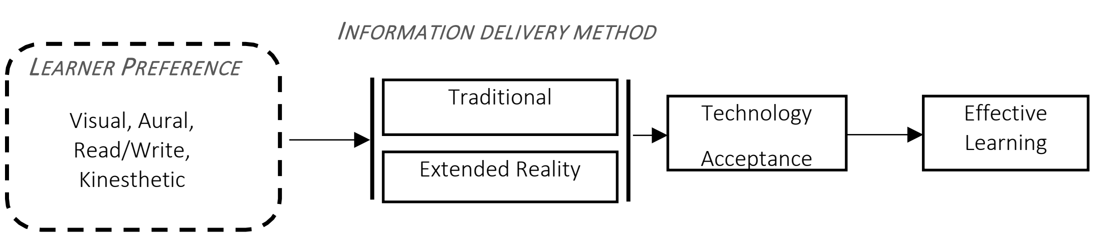

Figure 3: Effect of learner preference on information delivery methods

Identifying Learning Styles: VARK Learning Modalities

The VARK (visual, aural, reading and writing and kinesthetic) measures learning information and preference through sensory modalities (Fleming & Mills, 1992). Many studies have used VARK inventories (Bell et al., 2014; Drago & Wagner, 2004; Lau, et al., 2015; Lujan & DiCarlo, 2006; Marcy, 2001; Wehrwein, Lujan, DiCarlo, 2007). Fleming & Mills (1992) suggested four perceptive modalities that indicate learners' experience and constructs a measurable learning preference for efficiently attaining and recalling information. Researchers have used the VARK Learning style inventory because of its simplicity and reliability. Leite, Svinicki, and Shi (2010) conducted factor analysis and evaluated VARK inventory which confirms its validity as the reliability coefficients in their test appeared to be satisfactory.

Visual learners learn best by seeing various pictorial and graphical contents as symbols, charts, diagrams, illustrations, videos and such instead of words or listening. Aural (or auditory) learners acquire information most efficiently by hearing from discussions, lectures and conversations. Reading and writing learners prefer to take the information provided through words and texts. Their preferred method of obtaining information is through textbooks, taking notes, readings, and printed handouts. Kinesthetic (or tactile) learners prefer to gather information by touching and doing, through hands-on experience and trial and error. Some learners do not have any specific preference and learn efficiently using multiple of these modalities. These type of learners are referred as multimodal learner.

Methods

A quantitative research method was adopted in this study using analysis of subjective survey data. A small number of interior design students participated in the study. Their responses were examined to find answers to the research questions. Information delivery method in the design studio was considered as the independent variable which had two levels: Traditional and Extended Reality (XR) based instructions. Learner preference was included as a moderating variable while technology acceptance model was used as dependent variable.

Following are the questions this research seeks the answer of:

How do Information delivery Methods (Traditional, & XR) and learner preference affect the learning outcome?

a. How technology acceptance is affected by information delivery method?
b. How learner preference interrelate with the information delivery methods that affect overall learning outcome?

Hypotheses for questions a & b-

H1: The type of information delivery methods used in design pedagogy affects the perceived ease of use (PEU) of the information delivered.

H2: The type of information delivery method used in learning process affects the perceived usefulness (PU) of the information delivered.

H3: The learning preference of the user assumes the Perceived Ease of Use of the information delivery modality.

H4: The learning preference moderates the Perceived Usefulness of the information delivery modality.

In this study universal design strategies and its application in residential settings were used as the information delivered to a small number of interior design studio students. Universal design focuses on manipulating and designing a built environment for not only accessibility but also to accommodate greater extent of users regardless of individuality, culture and ability. Two interfaces were used for information delivery: traditional text and image-based and XR based interface. Thirty-two volunteers participated in the study. After the institutional review board approval, purposeful sampling was used to select the participants who are design students (juniors, seniors and graduate) at a Midwestern university in the US. The participants were then randomly assigned to either of the two interfaces for delivering information. Following is demographic information of all participants.

Table 1: Demographics in the Two Groups

	Gender		Age			Academic		
	M	F	18-25	30-35	35+	Senior	Junior	Graduate
Traditional	1	15	14	2	0	10	2	4
XR	2	14	14	1	1	9	3	4

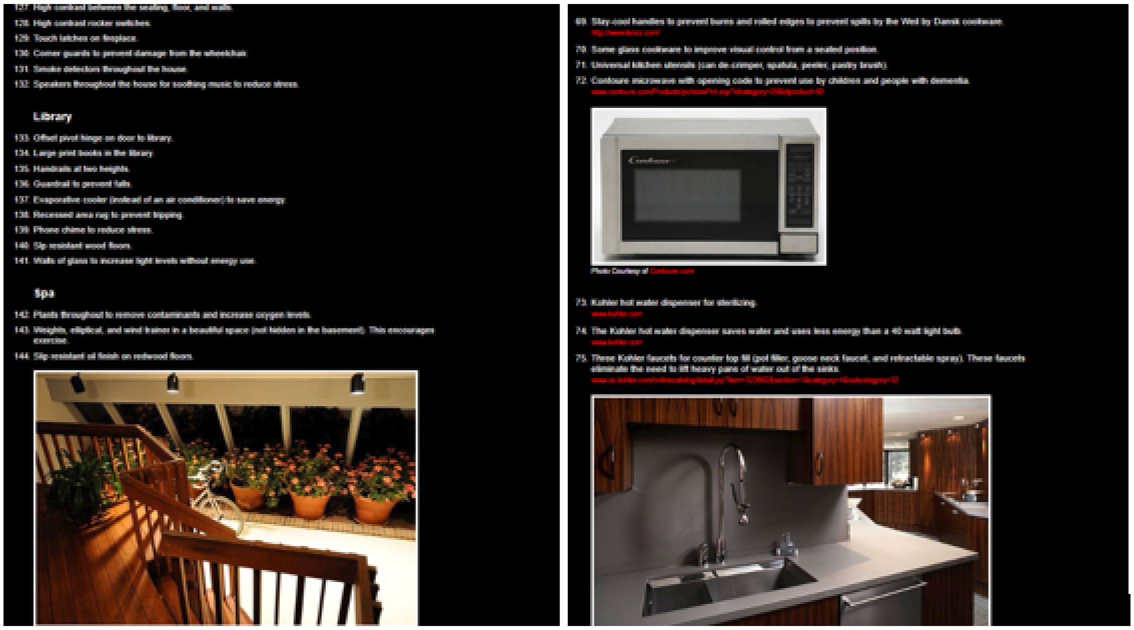

FIGURE 4: TRADITIONAL METHOD OF INFORMATION DELIVERY

Information regarding applications of universal design was given to the participants using traditional text and image-based method using pdf file format on computer monitor. Participants were asked to read the document as provided material given by the studio instructor after lecture.

Secondly, in the Extended Reality participants used a Virtual Reality device (Oculus Rift®) attached to a computer. A three dimensional model of the same case study residence was prepared using Autodesk Revit and Unity 3D game engine. Later hotspot markers were applied to all key spatial and design attributes where universal design aspects were implemented. Using Oculus Rift head-mounted display device and controllers participants were able to move through the virtual environment (different spaces within the residence), interact with various components as opening doors, windows, kitchen cabinet doors, turning on and off lights and such to evaluate the accessibility and ergonomics, etc. At the same time gazing at or using controller button hotspots could be activated which allowed participant to see detailed description of the universal design attributes applied to that specific design features and fixture. Participants also could select from an array of different materials as carpet texture or furniture selections to experiment with multiple aspects of universal design in the context.

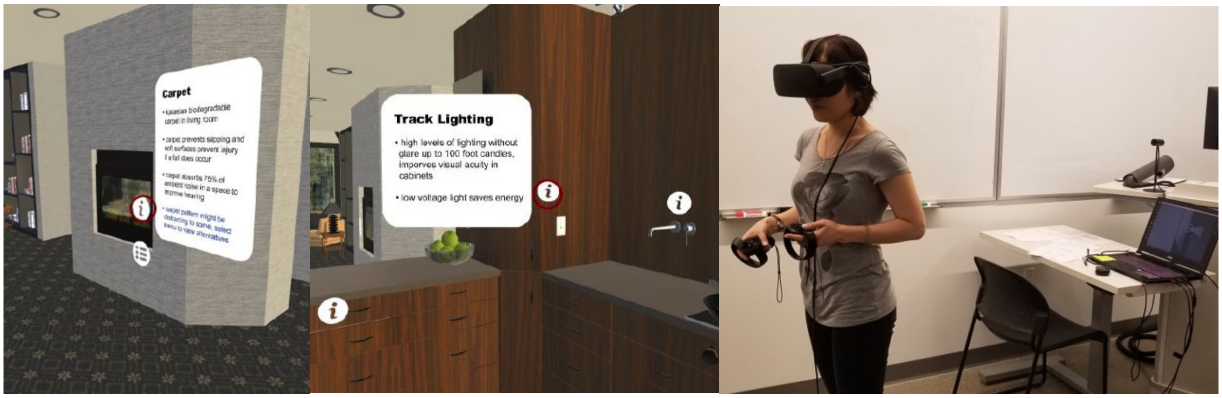

Figure 5: Extended Reality based information delivery

All participants from the two group were given the VARK learning styles inventory (pre-test) to identify their learning style and the technology acceptance model (TAM) questionnaires (post-test) to better understand participants' perception of these two information delivery methods and how it affects their learning preferences. The task in this experiment was to review and explore universal design strategies implemented in a residential case study through computer-generated Extended Reality environment and text and image-based document (Figure 4 and 5). To identify cognitive load associated with each of the information delivery methods all participants also answered the NASA task load index (TLX) questionnaire. NASA TLX can be downloaded and used for non-commercial use. The online version of this tool was used in this study and was administrated after the task was performed to obtain participants' perceived overall scores for cognitive engagement and load.

In short, this study expected that the learner preferences may affect and have a direct correlation with the information delivery methods in design studios which may affect learning performance.

Reliability and Validity

This study adopted the technology acceptance model (TAM) questionnaire from a recognized TAM scale to measure the subjective perceptions of technology use for delivering information in the design studio. A number of previous researches have validated TAM (Davis, 1989, 1993; Davis, Bagozzi, & Warshaw, 1989; Ong & Lai, 2006; Venkatesh & Davis, 2000; Venkatesh & Speier, 2000).

To measure learner preferences for visual, auditory, read/write, and kinesthetic learning styles the VARK Questionnaire for learning styles were used. The validity of the VARK as a learner preference identifier has been confirmed by many researchers (Bell et al., 2014; Drago &

Wagner, 2004; Karim, 2014; Lau et al., 2015; Leite et al., 2010; Marcy, 2001). After obtaining permission from the author online version of VARK questionnaire was used without alteration, therefore checking the reliability or validity was not essential.

Analysis and Discussion

Several studies conducted before have claimed that intrinsic motivation can directly impact learning. A high degree of Perceived Ease of Use (PEU) positively encourages learners' intrinsic motivation of an information delivery modality. Perceived Ease of Use, Perceived Usefulness (PU) and Behavioral Intention to Use (BIU) are some factors emphasized in the Technology Acceptance Model (TAM). Davis, Bagozzi, and Warshaw (1989) introduced the technology acceptance model (TAM) to address how users of commercial technologies accept and use the technologies. Recently, TAM has been used by educational researchers into the same settings. To identify the effects of learner preference on the two information delivery methods and relationship between them, Perceived Ease of Use (PEU), Perceived Usefulness (PU), and Behavioral Intention to Use (BIU) were compared between traditional and XR instructional method for two specific learning styles (kinaesthetic and visual).

Multiple statistical tests were conducted to examine the hypotheses. ANOVA (One-way analysis of variance) was executed to compare the dependent variables (PU, PEU and BIU) among two instructional modality types. Interaction between instructional methods and learner preference was described by performing a two-way ANOVA. The relationship between PU and PEU was measured using bivariate correlation coefficients (Pearson's r).

Comparison of the Dependent Variables (PU, PEU and BIU) between the two information delivery modalities

To analyze the difference between the two information delivery modalities (Traditional and XR based) and the dependent variables (Perceived Usefulness and Perceived Ease of Use) a one-way ANOVA was performed. See table 2 for descriptive statistics of PU, PEU and BIU by information delivery modalities. Table 3 shows ANOVA results for PEU, PU and BIU.

Table 2: Descriptive Statistics for the Traditional and Extended Reality based information delivery method

Dependent Variable	Independent Variable	Mean	SD
Perceived Ease of Use (PEU)	Traditional	4.093	0.663
	XR	5.282	0.901
Perceived Usefulness (PU)	Traditional	3.219	0.522
	XR	4.921	0.859
Behavioral Intention to Use (BIU)	Traditional	3.888	0.900
	XR	5.195	0.935

Note: N = 16 *(In each group)*

Table 3: ANOVA Summary Table for Information delivery modalities

Dependent Variable	Source	SS	df	MS	F	p
Perceived Ease of Use(PEU)	Between Groups	11.305	1	11.305	18.045	.001
	Within Groups	18.794	30	0.624		
	Total	30.099	31			
Perceived Usefulness (PU)	Between Groups	8	1	8	15.801	.004
	Within Groups	15.179	30	0.505		
	Total	23.179	31			
Behavioral Intention to Use (BIU)	Between Groups	13.676	1	13.676	16.221	.003
	Within Groups	25.292	30	0.843		
	Total	38.969	31			

There is a significant difference between the two method of information delivery modalities for all three dependent variables: PEU, $F(1,30) = 18.04$, $p = .001$); PU, $F(1,30) = 15.80$, $p = .004$); and BIU, $F(1,30) = 16.22$, $p = .003$). Means of all three dependent variables were significantly higher in the XR interface type, PEU: $M = 5.28$, $SD = 0.90$; PU: $M = 4.92$, $SD = 0.85$; and BIU: $M = 5.19$ $SD = 0.93$, compared to the Traditional interface type, PEU: $M = 4.09$, $SD = 0.66$; PU: $M = 3.21$, $SD = 0.52$; and BIU: $M = 3.88$, $SD = 0.90$.

Comparison of the Dependent Variables between Information delivery modality and Learner preference

Interactions among information delivery modality (independent variable) and learner preferences (moderator variable) on the technology acceptance measured through PU, PEU and BIU (dependent variables) was examined using a two-way ANOVA for each of the dependent variables. The effect of information delivery methods and learning styles on perceived usefulness was significant ($p < .005$). Comparisons between pairs of means (Table 5) shows that the mean value of perceived usefulness is considerably higher in the Extended Reality based information delivery method than the traditional mode of information delivery for the visual and kinaesthetic learner type.

Table 4: Descriptive Statistics for PU (Perceived Usefulness)

Information Delivery Method	Learner Preference	Mean	Std. Deviation	n
Traditional	Visual	3.8	0.758	5
	Aural	3.84	0.288	3
	Read/Write	4.51	.	1
	Kinaesthetic	4.05	0.480	5
	Multimodal	3.75	0.353	2
XR	Visual	4.62	1.198	4
	Aural	5.25	0.712	2
	Read/Write	4.5	0.353	2
	Kinaesthetic	5.29	0.827	6
	Multimodal	4.75	0.314	2

Table 5: Differences in Perceived Usefulness between Traditional and Extended Reality based information delivery methods by Learner preference

Learner Preference	Mean Difference	SE	p
Visual	-0.82	.398	.000
Aural	-1.41	.443	.389
Read/Write	0.01	.934	.312
Kinaesthetic	-1.24	.367	.004
Multimodal	-1	.451	.001

$p < .01$

To measure correlation among TAM variables *Pearson's r* were considered which suggest a positive correlation between perceived usefulness (PU) and perceived ease of use (PEU) on behavioral intention to use (BIU).

Table 6: Correlations among perceived usefulness, perceived ease of use and intention to use of information delivery modalities

		(PU)	(BIU)
Behavioral Intention to Use (BIU)	Pearson's r	$.819^{\#}$	
	Significance	.002	
Perceived Ease of Use (PEU)	Pearson's r	$.520^{\#}$	$.684^{\#}$
	Significance	.002	.000

Note: N = 32 $^{\#}$ $p < .001$

Cognitive load required to perform tasks with traditional and Extended Reality instruction method was compared using independent sample *t*-test. The difference appeared significant $p = 0.00546$ (table 7) suggesting cognitive load in Extended Reality based information delivery method was lower than the traditional mode.

Table 7: Overall Cognitive Load Measurement

	Cognitive Load (NASA TLX)		
Information Delivery Method	Mean	SD	n
Traditional	54.78	5.27	16
XR	36.76	3.97	16

df:28, P(T<=t) two-tail= 0.00546

Findings

This study investigated effects of technology acceptance on information delivery methods and relationship between learner preference and mode of information delivery to examine which instructional and information delivery method, using technology creates a constructivist learning environment for design students resulting effective learning.

Four hypotheses were tested as: i) information delivery methods has effect on perceived ease of use of the information delivered, ii) perceived usefulness of delivered information is affected by its method of delivery, iii) learning preference dictates the perceived ease of use of information delivery method and iv) learner preference also dictates the intention to use of information delivery modalities. Difference between traditional and Extended Reality based information delivery was significant for its perceived usefulness, behavioral intention to use and perceived ease of use. Participant design students perceived in this study that Extended Reality based information delivery were more useful than traditional text and image-based mode. Value of perceived usefulness and perceived ease of use were significantly higher in information delivered through Extended Reality for visual and kinaesthetic learners. Therefore, null hypothesis for hypothesis i-iv were rejected.

Researchers have used Technology Acceptance Model (TAM) in numerous occasions to identify motivation (intrinsic and extrinsic) to use and effectiveness of technology usage for performing a task (Fred D. Davis, 1989, 1993; V Venkatesh & Speier, 2000). Learners' perceived ease of use regarding a method assisted by technology to deliver information (instructions) affects intrinsic motivation (Viswanath Venkatesh, 2000); therefore, it encourages active use of information and enhances the learning process.

Conclusions

This study focused on identifying the relationship between users' perception of information delivery methods that promote a constructivist approach of learning and teaching in design studios. Therefore the research investigated association between user preference and effectiveness of the two modes of information delivery. Extended Reality based information delivery place the leaner in a three-dimensional virtual environment representing realistic representation of the world and its context. Users can interact with design elements and construct in-depth meaning while associating provided new information with existing knowledge and reflect in relation to the context. This also reduced required cognitive load to process and contextualize new information and encourage intrinsic motivation to actively learn compared to the traditional mode of information delivery that relies on text and images.

Design students are predominantly visual and kinaesthetic learners. Design education is generally based on various visuals and activities with physical elements. Individuals have different learning preferences which affects their learning effectiveness. Outcomes of this study suggest XR based information delivery method was easier to use and more effective than traditional means of teaching design ideas and principles. Selection of different types of instructional technology and methods affect how effectively learners construct meaning and use the provided information. This insight can be useful for design researcher and educator in developing a learner-centered constructivist design pedagogy.

Limitations

This study has several limitations. Besides relatively lower number all of the participants were from same geographical region and from one Midwestern University studying interior design. The study focused on only learning universal design's concept and its application as the information delivered. Even though the participants were randomly assigned to two groups, unequal distribution of gender and academic status may have contributed to results of the study. This is because some senior and graduate students are more experienced and have exposure to the information derived from other source.

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