The challenge of designing instructionally sound virtual reality-based training

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ABSTRACT

Instructional designers can have a profound impact on the bottom line of every corporate and industrial organization. Training Magazine's 2016 Training Industry Report found that U.S.-based educational institutions and corporations with 100 or more employees spent $70.65 billion total training expenditures in 2016; flat from $7.6 billion in 2015. Training expenditures per learner in 2016 was $814, which is up from $702 in 2015 (Training Magazine, 2016). However, actual hours of training per employee decreased from 53.8 hours in 2015 to 43.8 hours in 2016 (Training Magazine, 2016). Implementing technology-based training programs is more expensive but decreases the amount of time needed to train the workforce.

Instructional designers often rely on theoretical knowledge to account for allowances and limitations of technology in order to determine if the level of effort to implement is worth the risk of possibly developing ineffective training. It is a delicate balancing act that could potentially cost the organization a great deal of money if the instructional designer misinterprets the technology use case. As yet, research has failed to study both the competence and practice of instructional design in a fully immersive virtual reality (VR) environment (Tracey & Boling, 2014).

This paper introduces a dissertation qualitative study that explores instructional design considerations when designing VR-based training. Using a modified Delphi research design, the results from this study will identify possible best practices that could be used by instructional designers when designing VR-based training in order to improve practice in the instructional design field.

ABOUT THE AUTHOR

Mia D. Joe, PhDc is a Project Manager for Educational Technology with Huntington Ingalls Industries, Newport News Shipbuilding (NNS) division. Ms. Joe specializes in educational technology focused on the analysis and identification of appropriate technology when designing instructional solutions. Ms. Joe has over twenty-seven years of instructional design experience. As a learning professional, she has developed and managed educational programs for two branches of the military, four federal government agencies, one state agency, one school system, and multiple corporate entities.

Ms. Joe has served as project lead for multiple shipbuilding educational research projects which focused on deploying new technology to various instructional design and workforce development initiatives. Ms. Joe is a Doctor of Philosophy candidate (PhDc) in Education, specializing in Educational Technology and has earned 122 credit hours towards completion. In addition, Ms. Joe currently holds a MS in Higher Education and a BS degree specializing in Instructional Design and Technology, Magna Cum Laude.

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INTRODUCTION

Instructional designers can have a profound impact on the bottom line of every corporate and industrial organization. Training Magazine's 2016 Training Industry Report found that U.S.-based educational institutions and corporations with 100 or more employees spent $70.65 billion total training expenditures in 2016; flat from $7.6 billion in 2015. The top two priorities in the training industry for 2016 were increased training program effectiveness and reduced costs by improving efficiency (Training Magazine, 2016). Training expenditures per learner in 2016 was $814, which is up from $702 in 2015 (Training Magazine, 2016). However, actual hours of training per employee decreased from 53.8 hours in 2015 to 43.8 hours in 2016 (Training Magazine, 2016). Implementing technology-based training programs is more expensive but decreases the amount of time needed to train the workforce.

Instructional designers are typically challenged to develop training that is more effective and efficient through the use of emerging technology. Instructional designers often rely on theoretical knowledge to account for allowances and limitations of technology in order to determine if the level of effort to implement is worth the risk of possibly developing ineffective training. It is a delicate balancing act that could potentially cost the organization a great deal of money if the instructional designer misinterprets the technology use case. Virtual reality (VR) is but one of many technology options open to instructional designers.

This paper provides a brief introduction to a dissertation qualitative study that explores instructional design considerations when designing VR-based training. It explains who instructional designers are and some of their challenges when incorporating emerging technology into learning activities. This paper also provides a theoretical foundation section that addresses theories and models typically used in instructional design and VR. Finally, this paper addresses the nature of the study, scope, limitations, and significance of the study.

Study Background

There has been a great deal of interest using VR for the purpose of education (Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). VR immerses the learner into a simulated environment which allows them to interact in a completely safe surrounding (Tanaka, et al., 2015). However, identifying beneficial instructional strategies and learning activities is challenging for learning professionals. VR is an emerging technology (Hanson & Shelton, 2008), so therefore there is very little guidance by way of research-based best practices during implementation.

There are many instructional designers who lack the theoretical knowledge to effectively apply evidence-based instructional strategies to the courses they design (Ertmer & Newby, 2013). Instructional designers must not only understand or describe how learning occurs, but also prescribe the appropriate instructional strategy to ensure that learning has occurred (Ertmer & Newby, 2013). Instructional designers typically use a model to develop effective and efficient learning solutions. However, instructional design models must consider the increased levels of interactivity within the VR environment when designing VR-based learning activities (Reigeluth & Frick, 1999). In addition, the immersive and experiential natures of VR must complement each other for true learning to occur (Freitas et al., 2010).

As yet, research has failed to study both the competence and practice of instructional design in a fully immersive VR environment (Tracey & Boling, 2014). The VR environment should represent reality, or the real world, as much as possible in order to yield realistic results. However, the VR environment will be devoid of the typical hazards often found in the standard industrial environment. The goal of this study is to explore the considerations of instructional designers when designing VR-based training. This study should provide instructional designer insights regarding design considerations specific to VR.

Research Questions

This study will focus on the following three central questions:

- What design elements do expert instructional designers believe should be considered when designing full immersion VR-based training?
- What practices do expert instructional designers use to overcome challenges experienced when designing full immersion VR as a medium for training?
- Which instructional design model do expert instructional designers believe would be most beneficial when designing full immersion VR-based training?

In addition to asking the previously mentioned research questions, the researcher will also answer the following question based on participant responses.

- Which learning and instructional design theories are reflected in best practices identified by expert instructional designers when designing full immersion VR-based training?

THEORETICAL FOUNDATION

The theoretical foundation for this study is based on existing instructional design theories and models typically used during the practice of instructional design. This study will also use prior research as a means by which to gather data regarding instructional design of VR-based training. This theoretical foundation discusses existing theory first from which, as an interdisciplinary field, instructional design pulls from multiple instructional design theories and models. Instructional design, as an interdisciplinary field, draws theory from psychology, science, sociology, and education (Smith & Ragan, 2005). The primary research design of this study will draw from a design and development research (DDR) perspective. DDR is the systematic study of design, development, and evaluation of instructional and non-instructional products and tools (Richey & Klein, 2007).

The primary types of theory used in instructional design are descriptive learning theories and prescriptive instructional theories (Smith & Ragan, 2005). Descriptive theory describes how learning occurs, and prescriptive theories prescribe methods that increase learning (Driscoll, 2005). There have emerged seven primary instructional design theoretical contributions in the field; behavioral learning theory (Skinner, 1987), information processing theory (Miller G. A., 1956), Gagné's (1995/1996) theory of instruction, general systems theory (Banathy, 1992), cognitive load theory (Sweller, van Merrienboer, & Paas, 1998), situated learning theory (Lave & Wenger, 1991), and constructivism (Merrill, 1992). Thus, theoretical research in instructional design spans from 1956 to the present; which makes it a fairly new field that is just now beginning to define itself as an educational staple.

There are three primary groups of learning theory: behaviorism, cognitivism, and constructivism (Ertmer & Newby, 1993). Behaviorism is focused on observable behavior of the learner. Cognitivism is focused on psychological conditions as it relates to learning (Januszewski & Molenda, 2008). Constructivism is focused on the learner building their own knowledge (von Glasersfeld, 1995).

Behaviorism

Schunk (2012) defined learning as "…an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience" (p. 3). This definition clearly links learning to behavior in that it expresses two forms of the word *behavior*, as well as to consider the experience of activity. Driscoll (2005) defined learning as "…a persisting change in performance or performance potential that results from experience and interaction with the world" (p. 1). The terms *performance*, *experience*, and *interaction* leads the instructional designer towards behaviorist and activist principles, which are both characteristics of VR-based training.

Van Merrienboer and Bruin (2014) defined behaviorism as the theory where all learning is guided by the laws of classical or operant conditioning. Classical conditioning refers to neutral stimuli leading to automatic response and operant conditioning is based on reinforcement and more easily attained (van Merrienboer & Bruin, 2014). Despite the ensuing debate and misinterpretation of the definition of behaviorism (Moore, 2011), the majority of early instructional design models are based on the theory of behaviorism (Gustafson & Branch, 2007).

Another behaviorist law is operant conditioning which is based on associating stimulation with a positive or negative outcome, (Thorndike, 1911). Skinner (1938) made the most profound distinction between classical and operant conditioning by indicating that classical conditioning is programmed and results in automatic response while operant conditioning is a voluntary response. As an operant conditioning example, if the dog presses a button and is given meat powder, then this is a positive outcome that the dog will voluntarily continue to do. However, if the dog hits a bell and receives an electric shock, then this would be a negative outcome of which the dog would voluntarily refrain from doing. Both operant conditioning and classical conditioning are grounded by how learning is tied to physical behavior, or performance of the learner based on the definitions of learning provided by Schunk (2012) and Driscoll (2005) respectively.

The grounded premise surrounding VR is based on behaviorism which was initially presented by Watson (1913). Watson was the first to point out that learning objectives should truly be objective; instead of subjective by which to explain the student's expected behavior. Watson also indicated that observing the behavior of an *animal* not only displays current knowledge but also the animal's previous experience. For example, someone who learns how to tie a shoestring must first learn how to tie a knot and make loops in order to be successful. The action of tying a shoestring includes multiple learning objectives which serve of previous experience.

The purpose of workforce training programs is to improve the trainee's behavior and individual performance on the job. A skilled workforce is constructed by completing required tasks or acquiring the skills to complete the required tasks. Before the emerging technology of VR, trainees were focused more on gaining the knowledge but were unable to physically apply/translate this knowledge from a behavioral perspective in the industrial setting until participation in on-the-job training. VR affords the worker and opportunity to experience their own behavior while at the same time allowing others to observe the learner's behavior. It represents the practical application of a learned behavior which strongly ties VR to the theory of behaviorism.

As a learning theory, behaviorism speaks directly to VR in that the simulated setting allows for *hands-on* learning in a virtual environment that matches the real-world where the behavior will be performed. According to Skinner (1938), behaviorism is the philosophy where learning is based on observable performance that clearly shows a change of the learner's behavior when completing tasks. Skinner is credited with what is known as *radical behaviorism,* which removed the focus of learning from *the mind* to knowing what is learned due to behavioral observation. The VR environment relies specifically on observational behavior of the learner by either an instructor or software that is programmed to automatically detect and evaluate the learner's behavior. This fact brings the discussion of behaviorism full circle in that not only does the learner experience the task but also able to receive feedback through observation and feedback from the instructor, or what Skinner coined as the *programmed learning*.

Skinner (1958) indicated that information presented to the student in any form was not enough to learn. His focus on the student led him to develop a *teaching machine* (p. 1), which was meant to encourage the student to become more of an active participant in their own learning. The concept of a teaching machine was based on the premise that students learn by developing the desired behavior instead of being told how to behave (Skinner, 1958). In this respect programmed learning simply used instructional design techniques where evidenced-based research was used to encourage the expected behavior change. For example, Skinner's (1958) teaching machine's content was programmed to begin with small steps and advance to more difficult steps. Today's self-paced learning which happens to involve technology is nothing more than modern day teaching machines, or programmed learning (Driscoll, 2005).

Harzem (2004) proclaimed that behaviorism does not exist exclusively in and of itself because it exists in all learning. The instructional design perspective of behaviorism is concentrated in the identification of learning/performance objectives and the environmental conditions in which learning occurs (Ertmer & Newby, 1993). Another perspective of behaviorism in instructional design involves the concept of reinforcement which indicates that the desired behavior increases when instruction is reinforced (Driscoll, 2005). The behaviorist philosophy indicates that the learner creates the desired behavior after being informed of the objective, in the appropriate environment, with reinforcement when necessary. VR allows the learner to practice the desired behavior until the task, or action, is perfected. Observing the change in behavior gives the teacher the ability to confirm that learning has occurred by the student's ability to successfully complete the task. However, there are aspects of learning that is not visually observable which is contributive to a more cognitivist approach towards learning.

Cognitivism

Cognitivism is strongly tied to the study of internal mental structures involved with student learning (Bower & Hilgard, 1981). Learning from the cognitivist perspective is concerned with what the learner knows and how they came to know it (Jonassen, 1991). The cognitive theory more closely related to VR is situated cognition theory where there is more of a focus on the learning environment and activities (Driscoll, 2005). According to Wenger (1998) the premise surrounding situated cognition contains the following foundational principles:

- Humans are social.
- Knowledge is competence- and value- based.
- Knowledge is a matter of active engagement.
- Learning produces meaning.

At the center of situated cognition theory is the concept of legitimate peripheral participation (Lave & Wenger, 1991). For example, the layperson who is without the benefit of practical experience will have a different understanding than the more experienced tradesperson. In addition, by participating in the learning activity the layperson will become a practiced layperson as opposed to an informed layperson. Wenger (1998) referred to this as *negotiation of meaning* (p. 53), whereby the VR environment allows the layperson to learn through experience in essence becoming more aligned with the experienced tradesperson.

As the concept of situated cognition is relatively new, researchers continue to test and expand the knowledge base towards confirming validity of the theory. Grantham et al. (2013) conducted a study to test if situated cognition theory would describe the learner's cognitive process based on the environment of a learning activity. Zachary et al. (2013) applied situated cognition theory to explain the decision-making process of grocery shoppers. Gomez and Lee (2015) conducted a qualitative analysis to study the expanded level of knowledge attained using the social aspect of situated cognition theory.

Grantham et al. (2013) used the situated cognition theory to describe learning activity efficacy on cognition of the learner. The researchers used first-year engineering students at two different universities to complete a task to redesign a coffeemaker. In this particular instance the students represent the layperson and will have an opportunity to practice the engineering processes used by career engineers. Without the benefit of practicing the reengineering process, these students would not have had the opportunity to experience the actual work environment. The researchers found that situated cognition not only improved the product redesign, but also positively impacted learner creativity.

Zachary et al. (2013) conducted a study to understand how people make decisions to purchase certain types of groceries. Approaching the study from an ethnographic perspective the researchers conducted in-depth interviews and focus groups of low-income African American families with children. The researchers found that situated cognition theory provided insight towards understanding participant behavior. The results showed that structural qualities of the supermarket increased unhealthy purchases and decreased healthy purchases. In essence, it was the supermarket environment itself that served as the contributing factor towards decision-making, or food selection.

Gomez and Lee (2015) compared formal and informal learning environments to enhance sixth-eighth grade student learning. The researchers observed teacher-student interaction in a formal classroom environment and mentor-student interaction in an afterschool program or informal environment. The researchers found that the informal environment with mentor-student interaction created a situated learning phenomenon that improved student skills and expertise. In addition, afterschool program projects were made open to the public which served as a critical avenue towards receiving multi-sourced feedback that proved to further develop the student. The researchers argued that the situated cognition theory served as a model of opportunity for the students to informally practice what was previously learned in the formal environment.

As it relates to VR, the cognitivist approach involves presenting information that offers context to the learner (Ertmer & Newby, 2013). A large piece of VR is visual and, therefore, tied to the visual perception of the learner. There have been studies that closely tie cognitive and physical processes, meaning one affects the other (Wilson, 2002). Chao, Haxby, and Martin (1999) conducted a study that found when people were required to view and name a picture of a tool it activates premotor areas of their consciousness. This behavior was sparked simply by viewing the tool and, therefore, it stands to reason that the visual component within VR not only triggers the psychomotor reflex but also allows the learner to act on the visual representation.

Cognitivism is important to the learning process in that it addresses prior knowledge of the student, motivation of the student, and student reflection of the learning event (Anderson, 2008). To attain maximum learning instructional strategies should not only help the student understand the information, but also increase the rate of their comprehension. Instructional strategies, such as VR, that tap the learner's prior knowledge will help them form connections from long term memory to construct new meaning (Anderson, 2008).

Constructivism

The constructivist perspective implies that learning occurs when the learner creates their own reality based on their personal experiences (Ertmer & Newby, 2013). These experiences continue to build on one another with the learner forging a new reality with each new experience. Von Glasersfeld (1995) believed that as the teacher presents the problem the learner explores the information further to build their own knowledge which serves as the premise behind constructivism. Building knowledge includes actively constructing knowledge and skills and is considered learning (Branch & Kopcha, 2014). The quality of the learning experience has a direct effect on the learner's ability to construct the desired knowledge (Dewey, 1938). There must be some prior knowledge on which the learner can build (Schunk, 2012). Instructional design from the constructivist perspective is to assume that the learner will construct their own knowledge through the benefit of receiving a quality learning experience. VR plunges the learner into the industrial environment without the typical safety concerns often found in the real-world, or even the training environment. The constructivist instructional designer develops instruction that places the learning experience in the most appropriate context.

Constructivist principles are commonly integrated into simulation-based learning activities. The virtual environment serves as an opportunity to incorporate constructivist learning activities into the process of learning. Practical constructivism features include cognitive activity in a context that is built on prior knowledge then quickly applied through practical exercise with feedback and self-reflection (Baviskar, Hartle, & Whitney, 2009). The learner constructs their own knowledge while in the process of experiencing, or practicing, the learning activity.

A key constructivist was Lev Vygotsky who was a psychologist from Belarus that went mostly unnoticed until the 1960s (Driscoll, 2005). A primary Vygotsky viewpoint is surrounded by something known as the Zone of Proximal Development (ZPD) (Vygotsky, 1978). ZPD represents the point between the learner completing the task with assistance and the learner completing the task without assistance (Schunk, 2012). Vygotsky's definition is more intellectual in that he defined it as: "… the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p.86).

According to Vygotsky (1978) the ZPD specifies the point at which actual learning occurs. To this point, Vygotsky determined that the ZPD only provides a window into what has developed but does not provide details regarding potential development (Driscoll, 2005). Vygotsky also considered the strong social aspect of ZPD in that the level and quality of instruction does have a solid relation to a higher level of learning regarding potential development (Vygotsky, 1978). Vygotsky was considered more of a social constructivist in that he realized the role of the experienced person to guide the process of learning (Vygotsky, 1978). He believed that providing assistance and then systematically removing assistance, or scaffolding, allows learners to build or construct their own knowledge.

From the constructivist perspective, the role of instructional design is to provide realistic learning environments that will encourage critical thinking and problem solving which enables and enhances learning (Yoders, 2014). This is the instructional designer's challenge in that constructivism is more directed towards a less structured learning environment where the student is allowed to discover instead of individual instruction. As a result, constructivist instruction tends to be more conducive to an informal learning environment that is highly focused on the student's ability to learn through actual experience. For example, trade specific learning is usually taught through cognitive apprenticeship, or mentoring philosophy, within the actual trade-specific setting instead of a classroom environment. Not only does the learner learn from a seasoned tradesperson but they also become acclimated to the surrounding environment. Dewey (1938) reasoned that knowledge was not only representative of reality but is instead the process by which the individual is part of the reality through interaction. The more practical the learning environment the more likely information will be retained and the learner will actually experience completing the task; a philosophy clearly associated with the concept of VR.

Other Theories

Behaviorism, cognitivism, and constructivism are the primary theories that will guide this study, but more must be considered when technology enters the equation. The technology of VR requires additional theories to define the concept towards applied learning. Experiential learning, as a subset of constructivism, plays a large role towards prescribing learning outcomes. Kolb (1984) indicated that experiential learning is based on the learner constructing knowledge by interpreting their learning experience. However, the realm of educational technology is even newer than instructional design and has embraced a newly developed theory called activity theory. Activity theory lends itself to the educational technology research (ETR) premise that learning is based more on learner activity than on the content being presented (Karakus, 2014). While cognitivism is an important learning theory, VR is mostly focused on behaviorism, constructivism, and experiential learning theories as they are more closely tied to the activities involved with VR-based learning.

This study's approach to instructional design follows Branch and Kopcha's (2014) perspective in that it is based on a systematic model driven by complex educational contexts. The research design serves to organize the study which is similar to how instructional design models are practiced by instructional designers. The instructional design models are currently being used to encourage learning during the instructional process (Spector, 2014). The instructional designer's selection of a particular model is often based on one of three factors: employer, education, and timing. Oftentimes, organizations and institutions adopt a specific instructional system design (ISD) model by which all employed instructional designers should follow when designing corporate training or academic courses (Obizoba, 2015).

NATURE OF THE STUDY

This study will be a qualitative study using a modified Delphi method of inquiry directed to a panel of at least 10 expert instructional designers. Delphi technique is typically used to gather and distribute expert insights and conclusions on a particular topic or problem, as well as encourage consensus towards a specific solution(s) (Donohoe, Stellefson, & Tennant, 2012). Experts will be selected in the field of instructional design and requested to participate in the study. They will be asked their opinion regarding design considerations for full immersion VR-based training. Multiple rounds of questionnaires will be administered to build on patterns identified during the previous round of questioning.

After data collection the focus of the study will shift to data analysis. The primary focus of qualitative study is to describe an event, phenomena, or feeling (Patton, 2002). This is not to imply that data collection and analysis of qualitative research is linear but instead it is more like a cyclical process (Creswell, 2014). It is for this reason that the researcher will rely on multiple rounds of questioning to increase the likelihood of identifying patterns and themes. It is very possible that the process of analysis will illuminate the need for additional data collection. From there, the researcher will critically review the data to identify meaningful patterns through the use of computer software (Miles, Huberman, & Saldana, 2014). NVivo, as one of many types of software will not only help manage the data but will also help organize the data.

SCOPE AND DELIMITATIONS

The scope of this study addresses three utilities; instructional design, VR, and training. Instructional design is studied due to the challenges experienced by instructional designers when developing technology-based solutions. VR is studied due to the challenges experienced by instructional designers when implementing an emerging technology into learning environments. Training is studied due to the intense need of industrial environments to provide more effective and efficient training in a relatively risk-free environment.

This study will be a semi-structured qualitative Delphi method of inquiry on the design elements used for VR-based training by a panel of expert instructional designers. The participants will be carefully screened practicing instructional designers, who serve as the panel of experts. Multiple rounds of questionnaires will be administered to build on patterns identified during the previous round of questioning. The researcher will use the panelist textual responses to identify patterns in order to identify patterns and themes. Findings will be solely based on responses and ratings received from the panel of experts. Transferability is possible with this study but acquiring a different group of panel experts could yield similar or different results based on the selection criteria.

LIMITATIONS

Limitations in using the Delphi technique include the amount of time required to complete the study and level of experience of the panelists (Nworie, 2011). The multi-round nature of this methodology could result in attrition. In order to increase the number of participants, panelists will be asked to provide recommendations for other participants as a process of snowball sampling (Patton, 2015). The more participants in the study the more opinions, but at the same time the more participants the harder it will be to acquire consensus. It is recommended that 10-18 expert panelists be used for a Delphi study (Okoli & Pawlowski, 2004)

Participant selection criteria will be based on the number of years of instructional design experience as well as the types of organizations where the experience was gained. The study will be limited to participants who have at least ten years of instructional design experience, completed more than ten instructional design projects as the practicing instructional designer, a degree/certificate in instructional design, education, or other business-related degree, industrial-based training experience, and incorporated various forms of technology into instructional design projects. As this research specifically involves training, participants will be selected from industrial organizations. Additional selection criteria will also involve the types of courses designed by potential participants. All participants will have designed courses that have involved various forms of technology. As this training is specific to the emerging technology of VR, it is important that participant instructional designers bring prerequisite knowledge regarding challenges consistent with similar types of technology-based learning.

SIGNIFICANCE OF THE STUDY

Study of the instructional design aspects and models used to create VR-based training is important for several reasons. This research will enhance the fundamental understanding of designing fully immersive VR-based training. The results of this study will help fill a research gap as current studies primarily focus on developing desktop VR-based training. Fully immersive virtual environments add to worker experience by allowing workers to experience seemingly unsafe environments without relatively risking their safety and potentially their lives. The results from the study may also be used to provide guidelines to design fully immersive virtual environments and thus provide a cost-savings to businesses by decreasing overall training development time.

Significance of Practice

The results of this study will advance the practice of instructional design by providing guidance for instructional designers when developing VR-based training. The results will yield a listing of best practices to be used when designing training using VR technology. Identification of best practices will decrease the amount of analysis typically performed by instructional designers during the early stages of instructional design.

Significance of Theory

The usage of the term ‘theory’ in this study is geared more in a nonstandard context. In this study the term ‘theory’ is more in line with Maxwell’s (2013) explanation which leans more towards “a set of concepts or ideas and the proposed relationship …” (p. 48). Theory in this study is used more to provide explanation towards the practical application of instructional design during the development process.

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