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A COMPREHENSIVE RUBRIC FOR EVALUATING EDUVR

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ABSTRACT

Aim/Purpose	This article presents a comprehensive rubric for evaluating educational virtual reality experiences for mobile devices. The aim of this article is to systematically analyze research to address the quality of virtual reality experiences on mobile applications in order to extend the work of Lee and Cherner (2015) and their instructional application rubric.
Background	Ratings in proprietary mobile application stores – The App Store and Google Play, etc. – are generic and do not provide meaningful evaluations of the virtual reality. This article utilizes research in the areas of virtual reality and education to present a comprehensive rubric for evaluating educational virtual reality for mobile applications, which continues to advance previously published, research-based rubrics.
Methodology	The methodology uses a systematic process that spans multiple stages. The first stage was to locate pre-existing rubrics for virtual reality, followed by a review of literature focused on it. The third stage was to develop and vet a research-supported rubric for evaluating educational virtual reality.
Contribution	The main contribution from this article is that it fills a gap in the literature by presenting a criterion-referenced, research-supported rubric for evaluating the quality of educational virtual reality for mobile devices (e.g., smartphones, tablets, and app-connected goggles).
Findings	This paper's findings include the domains, dimensions, and criterion-referenced Likert scale indicators in the form of rubric dimensions for evaluating educational virtual reality. The evaluative domains consist of (1) Positioning of the EduVR, (2) Avatar Level, (3) Virtual Environment, and (4) Virtual Experience.

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Recommendations for Practitioners	This rubric is a tool for instructional coaches, teacher educators, and instructional technologists to use when recommending virtual reality experiences for instructional purposes.
Recommendations for Researchers	Researchers can use this tool to monitor the quality of educational virtual reality being developed for classroom use. They can also use this rubric to examine educational virtual reality experiences they would use in their studies and evaluate how those educational virtual reality experiences impact student learning, engagement, and collaboration.
Impact on Society	We foresee this rubric being an aid in the development, selection, and purchase of educational virtual reality by educational institutions, educators, researchers, edtech developers, and edu-philanthropists, thus advancing the quality and expectations for educational virtual reality experiences.
Future Research	Future researchers can further enhance the validity of this rubric by collecting large amounts of data from a diverse set of end users and stakeholders. Also, subsequent rubrics for evaluating augmented reality and extended reality comprise additional research avenues.
Keywords	virtual reality, VR, eduVR, educational apps, mobile learning, mobile apps, rubric

INTRODUCTION

Virtual reality has the potential to revolutionize the learning experience. Virtual reality provides students with experiences that would have otherwise been inaccessible. It allows students to visit remote places, collaborate in digital environments, and have experiences that are not physically possible, such as walking on Mars or traveling through the body on a blood cell. In addition, virtual reality experiences are becoming more accessible across devices – from complex headsets with built-in microphones and handheld remotes to simple cardboard viewers – and less cost prohibitive, which has spurred a boom in the educational technology marketplace.

New advances in technology coupled with the shift to remote instruction has caused tremendous growth in the global educational technology marketplace. Currently estimated at $268 billion and expected to grow to $404 billion by 2025 (HolonIQ, 2020), immersive technologies like virtual reality are driving that growth (Dick, 2021; Vlasova, 2020). The marketplace consists of educational institutions that purchase the educational technologies along with vendors, suppliers, investors, startup ventures, and technology companies that profit by selling their products to the educational institutions (Kellen, 2017). With the media reporting investments to develop virtual reality content by technology companies (Grubb, 2016; Merel, 2020) along with philanthropic efforts to improve all schools' access to technology (Bill & Melinda Gates Foundation, 2020; Walton Family Foundation, 2018), it has resulted in a deluge of virtual reality applications (apps) – software programs that can be downloaded onto internet-connected mobile devices without having to restart the device – being developed for education. Though neither researchers nor the media have provided a reliable estimate for the number of virtual reality apps available for mobile devices, a cursory review of proprietary mobile application stores (e.g., The App Store and Google Play) evidence that a significant number of them already exist. However, substantiated evaluative criteria for assessing their quality is lacking, which makes establishing their educational value problematic. Therefore, educational institutions, educators, researchers, edtech developers, and edu-philanthropists are spending money on developing virtual reality for educational purposes without having a tool to systematically check its educational value, usability, and usefulness.

Lee and Cherner (2015) explained that the use of starred ranking systems with general user comments inside proprietary app stores do not provide nuanced understanding about a technology's functionality or its quality. This lack of understanding can result in teachers choosing lower quality technologies for their students. With the current demand and funding, developers are creating educational virtual reality – referred to with the term *eduVR* in this article – at a rapid rate. However, no evaluative criteria for analyzing the quality of virtual reality that can be used for education has been developed. In response, this article presents a comprehensive rubric for evaluating the quality of eduVR for mobile devices including smartphones, tablets, and app-connected goggles. This eduVR rubric functions as an addendum to extend Lee and Cherner's (2015) foundational instructional app rubric. This rubric can aid in the selection and purchase of eduVR by educational institutions, educators, researchers, edtech developers, and edu-philanthropists.

To present this rubric, the researchers will first review earlier rubrics designed to assess educational technologies and then share their methodology for creating a rubric designed to analyze eduVR. Next, they will use current research on designing quality virtual reality experiences to discuss each of the rubric's dimensions, and example eduVR that demonstrates the dimension will be described. To conclude, a full analysis of an eduVR experience in a mobile app will be shared to model the application of this rubric along with implications for using it.

REVIEW OF LITERATURE

Virtual reality is distinguished from other multimedia in three ways: immersion, interaction, and involvement (Pinho et al., 2009). The term eduVR encapsulates these virtual reality experiences that can be used for educational purposes, though eduVR may not be designed with educational purposes in mind, in the same way as apps created for entertainment can be used for educational purposes. If a virtual reality experience can be aligned to learning outcomes, it qualifies as educational with a context.

Research has indicated that high-quality eduVR can improve students' soft skills in addition to learning (Kickmeirer-Ruse et al., 2019; Zhou et al., 2018). For example, the immersive aspects of eduVR can develop learners' empathy for the subjects depicted in the experiences (van Loon et al., 2018). In addition, eduVR has been indicated to improve space and depth perception in students ages 12 to 15 (Sik-Lanyi et al., 2003). EduVR environments can replicate and enhance the collaborative interactions learners have in both traditional and online learning environments (Di Blas & Paolini, 2014). For example, results of a study by Di Blas and Paolini (2014) indicated that simultaneous group eduVR experiences with several students can stimulate students' sense of community and collaboration both with students inside the physical classroom and those participating remotely. In this context, Scavarelli et al. (2020) emphasize that eduVR should employ multiple pathways for users to engage the immersive content, by themselves as well as in groups, and they point to the Universal Design for Learning principles as being a guide for creating these experiences in more accessible manners. Such findings indicate that eduVR can impact students' general development of soft skills. In specific subject areas, eduVR has been shown to impact learning in different ways. When eduVR experiences include replicas of real people and places, learners can cultivate feelings of immersion and presence within the virtual reality environment (Slater, 2018). Feelings of immersion and presence offer enhanced student engagement (McKenzie et al., 2019) and active learning experience over learning through other types of media, such as textbooks or videos (Allcoat & Von Muhlenen, 2018; Fegely et al., 2020; Wang & Braman, 2009). This immersion can improve students' attitudes and achievement related to different subjects, such as science (Jitmahantakul & Chenrai, 2019; Sarioglu & Girgin, 2020), English (Chen, 2016; Ou Yang et al., 2020), and math (Stranger-Johannessen, 2018). EduVR provides a medium for learners to have experiences that would not normally be possible. For example, by using eduVR to learn history, learners can interact with and experience historical events instead of reading about them, thus enhancing their comprehension of the topic and aiding in the transfer of this knowledge into long-term memory (Domingo & Bradley, 2018). Findings of these studies indicate that high-quality eduVR can improve students' learning in multiple subjects, in addition to developing students' soft skills.

Why Rubrics?

The proprietary stores owned by Google and Apple that users must visit to download apps rely upon a rating system in which users rate an app out of five stars (Martens & Maalej, 2019). Users' ratings are pooled and averaged to produce an app's overall rating. However, the reliability and validity of such measurements is lacking (McIlroy et al., 2015), and there are two main threats to those rating systems: (1) the subjective nature of the 5-star rating, and (2) intentional bias in users' ratings. These aspects negate the reliability and validity of app stores' app ratings, which will be next explained.

Cherner et al. (2016) explained that the starred rating systems employed by app stores are fundamentally flawed due to their subjective nature:

> The shortcoming with these systems is specific criteria to differentiate an app that scores a "three" versus one that scores a "four" or "two" are not easily made. Why an app might score a "two" to one person may well be the reason another person scored it as a "three" or higher, which complicates the type of information that can be learned from the ratings. (p. 119)

Cherner et al. (2016) explained that these star scores do not provide a methodical or criterion-referenced evaluation of an app's content and quality, which results in a need to develop criterion-referenced instruments to help ensure consistent, reliable, and valid evaluations. While the personal subjectivities of evaluators are acknowledged as a limiting characteristic of rubrics as well (Cherner et al., 2016), the specific language of rubric indicators provides guidance for evaluators to select their scores consistently and accurately (Crusan, 2010).

Furthermore, app ratings can include numerous intentionally biased scores from both real and fake user accounts. Researchers have found that positive app ratings correlate with higher download numbers (Finkelstein et al., 2017; Martin et al., 2016). Driven by the financial reward of higher download numbers, app developers may turn to for-profit textual and/or star rating reviews (Xie & Zhu, 2015). For-profit reviewers may post misleading reviews to influence customers and benefit their financier. According to Martens and Maalej (2019), educational apps had the third-most fake reviews in Apple's App Store. Further, fake accounts known as bots can be deployed by the thousands to artificially inflate or deflate an app's rating. The algorithms that control the bots may be operated by the developers themselves or pay-for-ratings enterprises with thousands of bots. Martens and Maalej (2019) explain that app stores actively police their markets for bots, however, developers continue to sell both negative and positive reviews by the thousands. Finally, intentionally biased ratings from groups of real users to impact app ratings are a liability to app store ratings. As an example, jilted Robinhood users in 2021 banded together to intentionally tank the rating of the trading app with over 300,000 1-star reviews after they were temporarily restricted from purchasing GameStop stock (Duffy, 2021). Intentionally biased reviews and fake reviews from bots represent legitimate threats to app stores' star ratings and illustrate how such ratings are not a reliable metric for measuring an app's content or quality.

Outside of ratings, checklists for the evaluation of apps are problematic because they constitute a binary instrument with only "Yes" or "No" options. Using a checklist to evaluate an app simply reflects an accounting of the elements included in the app, but not a measurement of those elements' content or quality. For example, Balefire Labs (2013) developed an evaluative checklist for educational apps. The checklist included simple operationalized terms associated with generic elements found in educational apps. Users of the checklist could only indicate whether the app they were reviewing had (Yes) or did not have (No) that generic element. For example, an app may include error feedback to the user. However, that feedback may be confusing, untimely, undetailed, unhelpful, or erroneous in itself. Simply having error feedback present in an app does not necessarily make that app a high-quality educational resource. As such, "Yes" and "No" marks on a checklist provide only a tally of an app's general elements and do not constitute a nuanced review of its content or quality.

Evaluation of Early Educational Technologies

With the rise of digital technologies – starting with software programs and websites and extending to applications designed for mobile devices – researchers have studied both the technologies' functionalities and their implications for student learning. One of the earliest works in this area was produced by Reeves and Harmon (1993), and they established 14 dimensions for evaluating the pedagogical implications for using educational technologies due to a concern that "consumers of technological innovations for education seem to assume that because these innovations are advertised as effective, they are effective" (p. 220). In their work, each dimension analyzed a specific aspect of the educational technology (e.g., Goal Orientation, Teacher Role, Motivation), and they first described each dimension using current research and then positioned its topic on a continuum with two poles. For example, the Motivation dimension was explained as a primary factor for students' willingness to engage the technology, and it was situated between the poles of extrinsic and intrinsic motivation. No ratings or delimitations between the poles were offered, and precise distinctions between the poles could not be made. As educational technologies evolved, more detailed tools were needed to make nuanced analyses.

Rubrics for Mobile Devices

Mobile devices that connect wirelessly to the internet revolutionized educational technology. No longer were educators limited to software programs and slow-loading websites. They now had access to mobile devices (e.g., laptops, tablets, smartphones) that, along with a reliable internet connection, could almost instantly download applications (apps) to those devices. These advances in technology then necessitated the creation of rubrics for evaluating educational apps for mobile devices, and researchers responded. Walker (2010) created a rubric that evaluated apps based on their curricular connections, authenticity, feedback, differentiation, user friendliness, and motivation. Buckler (2012) created another rubric for assessing apps to support adult learners with special needs. These early rubrics were critiqued due to being underdeveloped, not utilizing prior research, and lacking applicability (Cherner et al., 2016; Lee & Cherner, 2015). To explain, both rubrics used general terms and unclear criteria to make evaluative decisions about the quality of apps. Detailed explanations that substantiated the rubrics and methods for establishing their validity were omitted. Ultimately, these rubrics were not widely adopted, but they exemplified the need for these types of evaluative tools.

By the early 2010s, schools across developed countries were launching 1:1 initiatives that supplied all students and teachers with a mobile device to use, and developers were designing and releasing apps at a rapid rate. During this time, Lee and Cherner (2015) and Cherner et al. (2016) published their comprehensive rubrics for evaluating educational apps. Lee and Cherner's (2015) instructional app rubric consisted of 24 dimensions that assessed apps based on their instructional features, design elements, and engaging qualities. Each dimension was aligned to the research base, similar to the form Reeves and Harmon (1993) used, but they included well-described indicators to rate apps from 1 (low) to 5 (high) on each indicator. The design of this rubric was well-received by the research community, as Mustaffa et al. (2016) reported that Lee and Cherner's (2015) rubric is "comprehensive enough to effectively evaluate all types of educational apps [and] … is also current and up-to-date where it takes into account today's approaches to teaching and learning" (p. 106).

Though trailblazing when each of these rubrics were released (Buckler, 2012; Cherner et al., 2016; Lee & Cherner, 2015; Reeves & Harmon, 1993; Walker, 2010), advances in technology, deeper understandings of the learning sciences, and subjectivities embedded within their dimensions have resulted in the need to update their work. The natural progression of technology along with the growing interest, investment, and availability of virtual reality in the market has again established a need for a new rubric designed specifically for evaluating eduVR.

An Addendum to Lee and Cherner's (2015) Instructional App Rubric

Lee and Cherner's (2015) instructional app rubric provides a strong foundation for evaluating educational technologies in the form of applications for mobile devices. Lee and Cherner included the dimensions of (A.) Instruction, (B.) Design, and (C.) Motivation. However, eduVR presents characteristics that are unique to having virtual experiences, and these areas were not addressed in Lee and Cherner's rubric. In response, this rubric works as an addendum to extend their rubric by including the dimensions of (D.) Positioning of the eduVR, (E.) Avatar Level, (F.) Virtual Environment, and (G.) Virtual Experience for evaluating mobile eduVR. The process used to create this extending rubric will next be explained.

Methodology

This rubric is the result of a systematic review of literature that spanned multiple stages. As will be shared, the researchers changed their initial intention for this work due to the lack of existing literature on the topic. This section will describe each stage of the process they used to develop the rubric and establish its validity.

Stage 1. Generating Domains and Categories by Reviewing Research

Before creating their rubric, the researchers conducted a systematic search for any pre-existing rubrics for VR. Their initial goal was to critically analyze these rubrics for any gaps and develop a suitable response. To conduct this search, they entered keyword combinations consisting of "VR rubric"; "virtual reality AND rubric"; "virtual reality education rubric"; "VR apps evaluation"; "virtual reality education apps rubric"; and "VR rubric dimensions" into the Education Resource Information Center's database, a major research university's library database, and Google Scholar. The quotation marks were used intentionally, so the database would report articles that contained both words as a term and not just single words. Search filters were used to limit the results to peer-reviewed, full text academic journal articles published between 2015 to 2019. The databases did report 11 results; however, none of them included a rubric nor evaluative criteria for assessing the quality of virtual reality experiences. In response, the researchers pivoted this project from analyzing the pre-existing rubrics to responding and developing the first comprehensive rubric to evaluate eduVR.

With this new goal, the researchers again searched the Education Resource Information Center's database, a major research university's library database, and Google Scholar using the same keywords, but this time without the quotation marks, using the limiters of peer-reviewed, full text, and academic journal articles. This search identified a total of 1,218 articles on the topic. After further evaluation, duplicates as well as those that were not full text, peer-reviewed, or from academic journal articles were excluded. The inclusion criteria stipulated that the articles must include specific implications for designing and using VR, not general references to its potential or predictions about its growth. Because they needed a wide swath of scholarly works, principles, and best practices for designing educational virtual reality and using it with students, the researchers read the articles' titles and abstracts of the articles reported in the searches. This resulted in 196 articles. When the researchers identified an article with the information they sought, they then reviewed it and its ancestral literature to confirm that it contained the information. If so, they followed Coffey and Atkinson's (1996) guidance for coding articles – by marking the text's keywords along with recording the researchers' own thoughts and ideas – and then sorted the articles based on related codes (Saldaña, 2016). Each article was coded by both researchers through this process, and they identified four separate initial categories based on the researchers' consensus of the similarity of the codes. They then reanalyzed the articles in each category, with the goal of making more nuanced distinctions, that led to the individual rubric dimensions. Table 1 shows this alignment of articles, initial categories, and finalized rubric dimensions.

Table 1. Alignment of relevant literature to rubric dimensions

Relevant Literature	Initial Category	Rubric Dimension
Archer & Finger, 2019; Annetta et al., 2008; Baylor, 2011; Heeter, 1992; Jamaludin et al., 2009; Jennett et al., 2008; Kavanagh et al., 2017; Kunz et al., 2009; Li et al, 2002, 2003; Page & Thorsteinsson, 2009; Roth et al., 2015; Schmeil & Eppler, 2010; Steur, 1992; Warburton, 2009	Virtual Representation	E1. Avatar Level E2. Interactions F1. Authenticity and Realism G6. Immersion
Crosier et al., 2002; J. Johnson, 2019; Kaufmann & Meyer, 2009; Kolb, 1984; Kwon, 2018; Lifton & Paradiso, 2010; Milgram, 1994; Puentadura, 2010	Learning Theory	D1. Use of eduVR D2. Educational Impact G1. Experiential Component
Alghofaili et al., 2019; Fernandez, 2017; Fisher et al., 1986; Galitz, 1985, 1992; Gavrielidou & Lamers, 2009; Reeves & Harmon, 1993; Vinson, 1999	User Experience	F2. Content Presentation F3. Navigational Aids F4. Multimedia Elements
Alghofaili et al., 2019; Archer & Finger, 2019; Bonner & Reinders, 2018; Crosier et al., 2002; Merchant, 2012; Schmeil & Eppler, 2010	Human Interactive Design	G2. Pathways G3. Dimensionality of Movement G4. Virtual Manipulatives G5. Specificity of Control

STAGE 2. DESIGNING THE RUBRIC

This stage's purpose was to create the actual rubric. To begin, the researchers met to outline a skeleton of the rubric based on the initial dimensions and domains shown in Table 1. Next, they searched for existing eduVR experiences on mobile apps to provide context for the possible high and low scores for each dimension. To ensure the match between the dimension and eduVR, both researchers tested the eduVR to confirm the pairing. If one researcher dissented, they agreed to locate a new piece of eduVR. After matching eduVR experiences with all 14 dimensions to provide context, the researchers then drafted five indicators for each dimension.

This rubric takes the form of a taxonomy, and it is depicted in Figure 1. At its highest level is the domain (e.g., D. Positioning of the EduVR). The letter D. is assigned to the first domain as this rubric is designed to be an addendum to Lee and Cherner's (2015) three-domain (A., B., & C.) Instructional App Rubric (Figure 2).

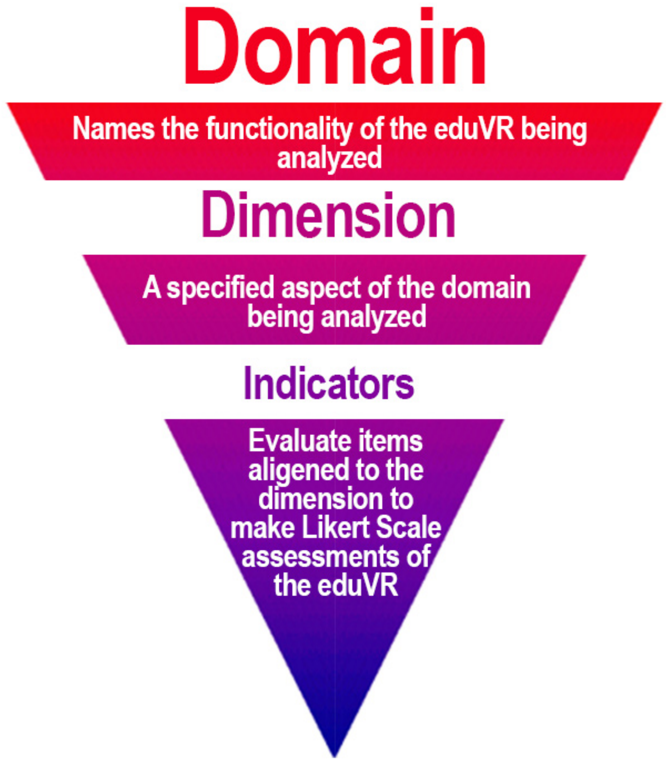

Figure 1. Taxonomy of evaluative domains

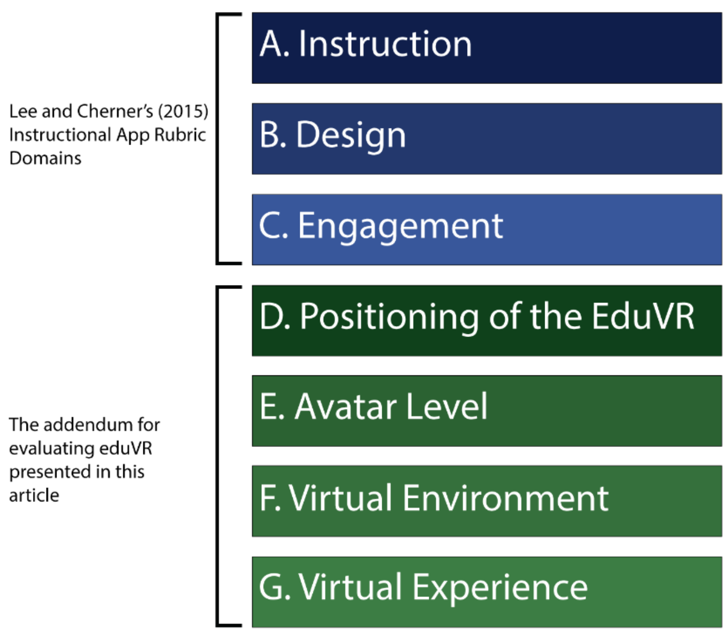

Figure 2. Addendum to Lee and Cherner's (2015) three-domain Instructional App Rubric

Each domain is then comprised of multiple dimensions (e.g., D1. Use of EduVR), and these dimensions describe the component of the eduVR being evaluated. Within each dimension are Likert scale indicators that range from 5 being the highest score an eduVR app can earn and 1 being the lowest. To further ensure clarity, specific language is used to describe each indicator, and that language was reviewed for clarity and jargon by experts in the fields of education, technology, and virtual reality. As the researchers' goal is for future researchers as well as practitioners to use the rubric, it was essential that the language was accessible and useful to both groups, and Table 2 presents the form and language used by the dimensions.

Table 2. Example rubric dimension

G4. Virtual Manipulatives: Within the eduVR, how can users interact with virtual manipulatives (e.g., objects, tools, multimedia) in the environment?					
5	4	3	2	1	N/A
The eduVR allows users to move and share objects in 3 dimensions (e.g., pick up and toss a ball to another avatar).	The eduVR allows users to move objects in 3 dimensions (e.g., pick up a ball, spin it top to bottom or side to side).	The eduVR allows users to move and share objects in 2 dimensions (e.g., hit an air hockey puck back/forth, left/right against each other).	The eduVR allows users to move objects in 2 dimensions (e.g., moving a pencil left/right, up/down).	The eduVR allows users to interact with objects in 1 dimension (e.g., pressing a button in).	Not Applicable

Stage 3. Validating the Rubric

To help ensure the rubric's face and content validities (Haynes et al., 1995; Lynn, 1986), the researchers formally presented the rubric to colleagues in a professional setting and then duplicated a method used by Lee and Cherner (2015) and Cherner et al. (2016). First, the researchers submitted this rubric in the form of a proposal to present it at an international conference. The proposal was accepted, and the researchers presented the rubric to 15 attendees who held doctorates in fields related to educational technology and were active researchers in the field of educational technology from around the world. After the presentation, the researchers asked the attendees for feedback and critiques in order to focus and revise the rubric. The attendees agreed that there was a need for the rubric, and they supplied significant feedback regarding the "Educational Impact" dimension. For example, there was discussion among the attendees about the advantages and disadvantages of using different frameworks for the Educational Impact dimension. In addition, they offered feedback for redrafting and rephrasing some of the rubric language, such as operationalizing terms, removing jargon, and splitting indicator elements of movement away from pathways. The attendees confirmed that the dimensions were logical and well delineated. With that feedback, the researchers used member checking to further validate the rubric.

In the same manner as Lee and Cherner (2015) and Cherner et al. (2016), the researchers built face and content validity in their rubric by seeking feedback from colleagues. Specifically, the researchers asked five colleagues from four different universities who were experts in using digital technologies and eduVR to record their feedback. The researchers used a questionnaire (Appendix A) to collect the feedback from their colleagues about each dimension. The researchers then used that feedback to revise the rubric and then re-sent the rubric along with the questionnaire for additional feedback. For instance, a sample piece of feedback from one colleague was, "I think you might want to clarify something about 'appropriate level of realism'. For example, *Toy Story* has the appropriate level of realism to communicate the message and for the audience to engage with the story." To address this concern, language was modified in the indicator, and "appropriately realistic" was used in the wording that describes a score of 5 in the Authenticity and Realism dimension. After two rounds of feedback, their colleagues did not provide any new feedback. At this point, the researchers finalized the rubric.

Stage 4. Futureproofing the Rubric

Currently, eduVR aligning to every dimensions' highest indicator does not exist for mobile devices, and the researchers relied on a "probable" future to complete select indicator criteria. To explain, the Futures Studies academic discipline is composed of four approaches to assist scholars with forecasting future trends: preferable, implausible, possible, and probable futures (Passig, 2003, 2009). "Preferable" futures are those which scholars mold through a shared vision based on their collective knowledge. "Implausible" futures are far-fetched ideas based on current knowledge. "Possible" futures consist of multiple different scenarios to understand the evolution of a concept based on current-day knowledge. "Probable" futures assume that there is logic to the evolution of a concept. Based on logic, this approach uses patterns to develop predictions for the future at the immediate, short, median, long, and very long intervals of time (Joseph, 1974).

The design of this rubric employs the "probable" futures approach for select language within the highest indicators for the dimensions of (E1.) Avatar Level, (G4.) Virtual Manipulatives, and (G5.) Control. Currently, the highest scores for these dimensions can only be achieved by either developmental virtual reality or virtual reality that needs to be connected to a desktop computer. Applying the "probable" futures lens with the knowledge that the technologies needed to achieve these highest scores already exist – but are not yet fully-available on mobile – the researchers future-proofed these dimensions to account for the natural progression of technology. In accordance with the "probable" futures model of the Futures Studies academic discipline, the researchers expect those dimensions' highest indicators to be available on mobile eduVR in the next 5-10 years at the latest.

Presentation of the Rubric

This section introduces the rubric created to extend Lee and Cherner's (2015) rubric in ways that are specific to eduVR experiences. To present the rubric, each domain and its dimensions will be introduced along with example eduVR within an app that is rated at the highest level according for each dimension. The complete rubric is available in Appendix B.

Domain D: Positioning of the EduVR

The following dimensions analyze how the eduVR is situated relative to the learning content. To evaluate an eduVR experience's positioning, the following two dimensions are used: (D1.) Use of eduVR and (D2.) Educational Impact.

D1. Use of EduVR

The "Use of eduVR" dimension evaluates if virtual reality is an appropriate method of delivery for the content. Milgram et al.'s (1994) Reality-Virtuality Continuum is used to analyze the amount of virtuality in an experience. On one side of the continuum is a completely physical experience. On the other side is a completely virtual experience. Between these two poles is mixed reality, which incorporates different levels of both physical and virtual components, and "each of these environments represents what is supposed to be a single, complete, and consistent world" (Lifton & Paradiso, 2010, p. 13). Parsons et al. (2019) explain that "where some learning activities are simple to host in an augmented physical space, … others are difficult or impossible, and would require a virtual space" (p. 147). Because virtual reality is only one modality along the continuum, this dimension analyzes if the eduVR delivers content to learners in a way that is appropriate and would not be better delivered through another method.

Example app for use of EduVR. For this dimension, eduVR scores well when the educational content aligns best to the virtual reality modality. For example, the Within app (Within Unlimited, 2019) includes an eduVR experience entitled The Source. In this eduVR experience, students accompany a 13-year-old Ethiopian girl on her daily journey through the desert to find clean water. This content would not make sense in mixed reality because the crux of the learning experience is based on taking part in a simulation of a day in the life of young girl who is in a likely completely unfamiliar and different environment from their own. Furthermore, this content would not make sense in a real-world, physical environment, as students taking a field trip to journey for clean water through a desert environment is both dangerous and impractical. Because The Source presents content through eduVR in a way that could not be better delivered through another technology or a real-world environment, it scores highly in this dimension.

D2. Educational impact

The "Educational Impact" dimension utilizes Puentadura's (2010) Substitution, Augmentation, Modification, and Redefinition (SAMR) scale to contextualize the effect an eduVR experience has over more traditional instructional tools. It is important to note that the SAMR scale does not account for variables such as learners' levels and lesson content, and researchers have critiqued SAMR due to its lack of validity, disregard for contextual factors, and use of technology for technology's sake (Cherner & Mitchell, 2020; Hamilton et al., 2016). However, SAMR does provide a scale to measure the type of experience the eduVR provides, from something that redefines what is possible to something that only acts as a substitute for a reasonably safe and accessible experience, such as walking through a park.

Example app for educational impact. Experiences in eduVR offering previously inconceivable opportunity for students rank at this dimension's highest level. For example, Wonda VR (2018) allows students to create their own eduVR experiences. Using this app, students can edit 360-degree-camera footage and add multimedia in order to create immersive eduVR experiences of their own. Because Wonda VR provides students the ability to create eduVR experiences that are only possible in a digital context, it ranks as a five for this dimension.

DOMAIN E: AVATAR LEVEL

The next dimensions analyze the appearance and interaction functionalities of eduVR's avatars. Researchers have found that virtual environments with avatars that use realistic graphics improve individuals' feelings of social presence and satisfaction (Annetta et al., 2008; Jamaludin et al., 2009; Warburton, 2009). To measure an eduVR experience's avatars, the following two dimensions are used: (E1.) Avatar Representation and (E2.) Interactions of Learners.

E1. Avatar representation

The "Avatar Representation" dimension evaluates the positioning of avatars within the eduVR experience. Page and Thorsteinsson (2009) explain that avatars give a "sense of emotional presence" (p. 7) that allows learners to engage the social and psychological aspects of communication. A lack of visual cues or anticipated reactions during communication in a virtual environment can be emotionally draining (Guye-Vuilleme et al., 1998; Page & Thorsteinsson, 2009), and researchers found that avatars' facial expressions and gestures remove the ambiguity of communication to enhance learning (Atkinson, 2002; W. L. Johnson et al., 2000; Lester et al., 2000). Avatars that appear lifelike with the display of emotional expressions have been indicated to increase learners' motivation (Baylor, 2011). Therefore, avatar representations that are as lifelike as possible sit atop this dimension.

Example app for avatar representation. Facebook's virtual reality avatar functionalities demonstrate this dimension's highest level. Shown on Facebook Reality Labs (Facebook, 2019), current face-scanning technology can be used to copy individuals' faces from digital images. A virtual reality headset with built-in cameras is used to map an individual's facial movements and synchronize the avatar's face with the individual's real-life facial expressions. The result is avatars that have synchronous and recognizable expressions. These avatars have the potential to boost learners' social presence and help them feel more connected in virtual communications (Facebook, 2019). Because of the incredible detail and lifelike avatar, Facebook's Reality Labs avatar technology highlights the level of authenticity needed to score high on this dimension.

E2. Interactions

The "Interactions" dimension analyzes the user-to-user interaction provided by the eduVR. While some eduVR experiences only include asynchronous user-to-user interactions, such as through messages or discussion board posts, more dynamic and synchronous interactions are possible. Using avatars in a virtual environment allows for greater openness, risk taking, and ease while working with other students in collaborative, real-time groups (Page & Thorsteinsson, 2009). As Schmeil and Eppler (2010) explain, virtual reality delivery "making use of the potential of virtual embodiment (i.e., being immersed in a space as a personal avatar) allows for innovative new forms of collaboration" (p. 121) that constitute this dimension's highest score. Therefore, multifaceted synchronous interactions between learners through avatars sit atop this dimension.

Example app for interactions. Engage (VR Education Holdings PLC., 2019) is a desktop computer-based virtual reality program that can be run on the Oculus Rift and other premium virtual reality headset platforms. Engage allows learners to take part in numerous synchronous interactions between multiple, photorealistic avatars. These synchronous avatar-to-avatar interactions include speech, movement, virtual manipulative sharing, 3-D modelling, and file sharing. In a time when working online or from distance is normalizing, eduVR experiences like Engage have the potential to redefine online learning, and it exemplifies this dimension's top rating.

Domain F: Virtual Environment

A virtual environment is a 3d simulation of either a real-world or computer-generated world (Chandrasekera & Yoon, 2018). Students often find virtual environments to be unauthentic (Kavanagh et al., 2017), and this dimension responds by analyzing virtual reality elements attributed to building authenticity within digital contexts and includes: (F1.) Environment Experience, (F2.) Content Presentation, (F3.) Navigational Aids, and (F4.) Multimedia Elements.

F1. Authenticity and realism

The "Authenticity and Realism" dimension examines the extent to which eduVR environments exhibit those elements. In this context, the term *authentic* means that the eduVR environment's digitization of the physical environment is accurate, reliable, and based on facts. Authenticity ensures that the eduVR environment looks and feels grounded in an accurate representation of the real world. According to Schofield (2014), the accuracy of the eduVR environment's measurements in instances where real world environments are replicated in eduVR is crucial as if provides the foundation for authenticity. The term *realistic* means that the eduVR environment is nearly indistinguishable from reality. The realism of the eduVR is aided by high resolution and field of view (Schofield, 2014). The indistinguishability of realism includes eduVR environments that replicate physical places using 360-degree camera footage and computer-generated reproductions of locations that allows learners to interact with and within the eduVR environment. Schofield noted that the realism of "items relating to specific learning objectives are usually the most important objects built and represented" in eduVR environments (p. 31).

Example app for authenticity and realism. The Anne Frank House VR experience for Oculus (Facebook Technologies, 2020) exemplifies the convergence of authenticity and realism. In the Anne Frank House VR experience, learners can tour the Anne Frank House and interact with different objects in the rooms. The eduVR environment is authentic because it is a computer-generated environment constructed on an accurate, fact-based, and proportional model of the real Anne Frank House.

Copies of the real-world items owned by those hiding in the secret annex that are now part of the museum are also available in the eduVR environment for learners to interact with. The eduVR environment is realistic because it provides high-quality graphics to enhance the experience for learners. Because of these reasons, Anne Frank House VR scores a five in this dimension.

F2. Content presentation

The "Content Presentation" dimension analyzes how the eduVR pairs multimodal elements with active and passive activities to engage learners in the content. Multimodal elements include text, images, audio, and video, and at least some of these elements are already commonly used in nearly all synchronous and asynchronous eduVR experiences. However, multimodal elements can be overused and become distracting in some learning applications (Schofield, 2014). Though synchronous person-to-person interactions are currently less common, they will become more prominent in the future (Fernandez, 2017), and they will foster higher levels of engagement between learners, with student-controlled avatars giving multimedia presentations in digital lecture halls to teacher and student avatars serving as an example. These future synchronous person-to-person interactions will feature multimodal elements to actively engage learners. When eduVR experiences can combine multimodal elements with synchronous interactions, it represents the highest score an experience can earn from this dimension.

Example app for content presentation. Those eduVR experiences that digitize a classroom environment exemplify active, synchronous engagement. In Rumii (Doghead Simulations, 2019), the environment is an actual classroom or conference room that students and instructors enter in the form of avatars. The instructor leads multimedia-rich lessons that engage students in active learning activities with their peers. For example, instructors can upload and teach their presentations with embedded multimedia elements for students in the eduVR classroom. In addition, the instructors can call on students to share their reflections on the lesson with their classmates in real time. Because Rumii utilizes both multimedia elements and active learning within its environment, it scores well on this dimension.

F3. Navigational aids

The "Navigational Aids" dimension evaluates the supports for learners as they maneuver within an eduVR environment. Alghofaili et al. (2019) note that virtual reality developers commonly neglect to help learners with in-experience aids for wayfinding through virtual reality worlds. Large-scale virtual worlds that are easy to navigate leave cognitive processing power for other tasks, because learners must employ multiple cognitive functions to create a mental model needed to navigate (Alghofaili et al., 2019; Vinson, 1999). While landmarks in virtual environments can be used to decrease navigational time and errors (Gavrielidou & Lamers, 2009), robust navigational information enhances situational awareness of learners (Fisher et al., 1986). In the absence of navigational aids, learners could become lost and frustrated with the virtual reality experience (Alghofaili et al., 2019). In response, this dimension evaluates the quality of navigational aids for learners.

Example app for navigational aids. The National Geographic Explore VR experiences within the Oculus app (Facebook Technologies, 2020) give learners the ability to explore Antarctica or Machu Picchu as photographers on photo assignments. Physical flags, interest markers, and signal beacons aid learners to journey through exotic and unfamiliar locations. With these navigational aids, learners are unlikely to get lost as they maneuver through the eduVR environments at their own pace. Due to the availability of multiple types of navigational aids, National Geographic Explore VR on Oculus scores a 5 in this category.

F4. Multimedia elements

The "Multimedia Elements" dimension assesses the seamlessness of the eduVR experience's multimedia elements, which consist of text, iconography, graphics, color, and other visuals (Reeves & Harmon, 1993). Parong and Mayer (2018) explain that positioning multimedia elements intuitively within a virtual reality experience results in higher levels of user interaction, and researchers (Galitz, 1985, 1992; Mayer & Fiorella, 2014) have found that high-quality integration of multimedia elements is critical for human-machine interaction because it eliminates extraneous cognitive processing. In turn, this dimension measures the level of multimedia integration within eduVR experiences.

Example app for multimedia elements. Organized multimedia that is flawlessly integrated into an eduVR environment and enhances learners' experiences score well on this dimension. The Oculus (Facebook Technologies, 2020) app's Virtual Desktop experience, for example, allows learners to access and use their computer's multimedia and associated programs in a variety of virtual reality environments. Learners could watch movies on their computer in virtual movie theaters or use Photoshop in a virtual world. Virtual Desktop allows learners to control their computer programs through the virtual experience, which includes the ability to move between an organized arrangement of multiple different screens and customize their floating screens. For these reasons, Virtual Desktop scores highly in this dimension.

DOMAIN G: VIRTUAL EXPERIENCE

Virtual Experience includes all the sensory, interactive, movement, and control aspects available to users while engaging with a virtual world. These dimensions focus on how virtual reality technology translates movements and interactions common in the physical world into a digital environment, and this domain includes six dimensions: (G1.) Experiential Component, (G2.) Pathways, (G3.) Dimensionality of Movement, (G4.) Virtual Manipulatives, (G5.) Control, and (G6.) Immersion.

G1. Experiential component

The "Experiential Component" dimension analyzes how the eduVR utilizes experiential learning to engage learners. Godat et al. (2007) explain that virtual reality can be used as a "transitional interface" between classroom learning and real-world learning aiding in the "transformation of conceptual learning to experiential learning" (p. 71). Kolb's (1984) experiential learning framework is typically used for direct learning experiences outside the classroom in which students observe, reflect, and internalize the application of abstract concepts in order to deeply conceptualize and engage them. Kwon (2018) found that the "enhanced vividness and interactivity" within virtual reality technologies allows learners to associate virtual experiences as direct experiences (p. 101). While real-world experiential learning opportunities such as field trips carry inherent safety and logistical concerns (Whitmeyer & Mogk, 2013), Crosier et al. (2002) note that virtual reality provides students with "safe environments for exploration and allow students to experiment with trial and error learning strategies without negative implications" (p. 79). Because connections exist across these findings, there is a reasonable expectation that virtual reality can be leveraged to provide students with the experiential experiences needed for learning, which is the focus of this dimension.

Example app for experiential component. The Wonders of the World eduVR experience on the Oculus (Facebook Technologies, 2020) app exemplifies the experiential learning activities needed to satisfy this dimension's highest score. In the experience, learners first pick their quest and their choices including exploring the Colossus of Rhodes, the Taj Mahal, or Machu Picchu. Next, when they enter the quest, learners can access multiple pieces of information by interacting with characters, investigating the area, and collecting artifacts. They then must use that information to complete the quest, which includes the use of abstract thinking to solve problems needed to advance through the experience. Throughout the eduVR, learners are engaging with content appropriate to the quest's context to learn about the time period while being in a safe environment. Because learners are building their knowledge by completing the experiences required to advance in the quest, this eduVR is rated as a five for this dimension.

G2. Pathways

The "Pathways" dimension measures the number of options available to learners as they move through the eduVR environment. Alghofaili et al. (2019) explain that digital environments can have "complex paths" (p. 1) that learners must negotiate, and there is a difference in the paths offered to learners based on how the virtual environment was created. For virtual environments that used a 360-degree camera to capture that environment, learners are typically restricted to the exact paths that the camera followed (Archer & Finger, 2019), which means they cannot move off the linear path traveled by the camera. Computer-generated virtual environments on the other hand are inherently more fluid because there are no limitations based on the footage and track captured by cameras (Archer & Finger, 2019). In addition, this dimension also considers the pace at which learners move through the environment, whether self-paced or regulated by the eduVR in some way, and eduVR environments that include limitless pathways for learners to navigate at their own pace score the highest in this dimension.

Example app for pathways. Walter's Cube (VR Space Holdings Inc., 2020) places learners in an art gallery, and they can move through it at their leisure. They are not confined to any paths nor paces, and barriers exist that impede their movement. Because learners can travel from piece to piece within the exhibit based on their own personal preferences, it exemplifies the top score for this dimension.

G3. Dimensionality of movement

"Dimensionality of Movement" evaluates the eduVR's level of movement on different planes within the environment. Movement in eduVR is typically measured by degrees of freedom, or the axes related to head rotation (Baruah, 2019). Dimensionality of movement in this case is more expansive than degrees of freedom and is measured from zero to three dimensions for learners in the eduVR environment. Zero dimensions of movement is when learners can only turn their heads and are unable to leave a set point. A half dimension of movement would constitute one-way movement, such as being able to only move forward. One-dimensional movement allows learners to move on a linear path, both forward and backward. Two-dimensional movement includes forward/backward movement and adds left and right movement abilities on the same plane. Three-dimensional movement includes the full dimensionality of movement humans enjoy in the real world: forward, backward, left, right, up, and down. Up and down movement in an eduVR environment may manifest as the ability to jump, climb, fly, swim, or float up and down. Schmeil and Eppler (2010) theorize that "an ideal online, three-dimensional virtual environment would provide a space in which users can move freely" (p. 121), thus, three dimensions of movement are ascribed to the highest level.

Example app for dimensionality of movement. The Ocean Rift virtual reality experience for Oculus (Facebook Technologies, 2020) gives learners life-like freedom of movement. In Ocean Rift, learners can swim forward/backward, left/right, and up/down to interact with different sea animals. Learners can move in the eduVR environment by either pantomiming a swimming motion with their handheld virtual reality controllers or moving with a button-based propeller tool. Due to the three-dimensional movement available to learners in this eduVR experience, Ocean Rift scores a five for this dimension.

G4. Virtual manipulatives

The "Virtual Manipulatives" dimension analyzes how learners interact with virtual manipulatives in the eduVR. Research suggests that the manipulation of objects in a virtual environment can impact learning (Bonner & Reinders, 2018), and virtual manipulatives can aid learners in the visualization and understanding of abstract concepts (Crosier et al., 2002). They also allow learners to interact with objects in the experience naturally, as they would in the real world (Schmeil & Eppler, 2010). Virtual manipulatives can be manipulated in one dimension (e.g., pressing an elevator button in), two dimensions (e.g., writing on a piece of paper), or in three dimensions (e.g., picking up a ball and tossing a ball). Virtual manipulatives can also be shared between learners for collaborative activities. Accordingly, eduVR experiences that score highly in this dimension provide learners with the ability to interact with virtual manipulatives in three dimensions and synchronously share them with other learners.

Example app for virtual manipulatives. This dimension's highest level is exemplified by Toybox (Facebook Technologies, 2020), a desktop computer-based VR experience for Oculus Rift. Toybox allows learners to interact as avatars by sharing virtual manipulatives in all three dimensions through life-like physics. Users' avatars can slide or toss the virtual manipulatives to themselves and other avatars within the virtual environment. These features exhibit complete freedom for interacting with and manipulating objects inside a virtual environment.

G5. Control

The "Control" dimension evaluates the extent of control learners have over their movements, manipulations, and dexterity in the eduVR experience. Merchant (2012) explains that virtual environments and objects can be interacted with through hardware and software controls – button, gaze, hand tracking, etc. – to create a more realistic interactive experience. With Bonner and Reinders (2018) finding that natural gestures within virtual reality aid in the learning process, this dimension assesses the control learners have of their movements in the virtual reality experience and the fluidity of those movements.

Example app for control. The ability to control users' movements, manipulation, and dexterity within the eduVR environment in a variety of ways scores highly for this dimension. Cubism Demo is a beta eduVR experience for Oculus (Facebook Technologies, 2020) that exercises learners' spatial thinking. Learners can grab and turn virtual manipulatives to fit into 3-D puzzles in visual and spatial tests. Cubism Demo scores highly in this dimension because it tracks learners' movements and copies their fingers' manipulations into the eduVR environment as translucent hands.

G6. Immersion

The "Immersion" dimension analyzes how present and absorbed learners are within an eduVR experience. Heeter (1992) defines presence as "the sense of being there" (p. 4) in relation to a virtual environment. Archer and Finger (2019) note that presence is "a core requisite for immersion" (p. 14), and they explain presence as the learners' perceptions that a virtual world is in fact real, and that they feel part of that virtual world by interacting with its various features. Immersion is then built on presence, and it consists of the high-quality sensory inputs (e.g., sharp, striking visual and audio features) that create a feeling within learners that they are actually in another place altogether. Some eduVR apps, like Tara's Locket (Big Motive LTD., 2017), even encourage learners to wear headphones, so they take full advantage of its sensory experience. Steuer (1992), explains that immersion in a virtual environment can be evaluated based on sensory richness, and deep levels of immersion can elicit emotional responses that lead to losing track of time while engaging the experience. (Jennett et al., 2008). These considerations for presence and deep immersion form the foundation for this dimension.

Example App for Immersion. The Mission: ISS eduVR experience on the Oculus (Facebook Technologies, 2020) app stimulates learners' sensory inputs through vision, sight, and touch. To build presence, learners can interact with the model of the International Space Station, grabbing and floating from one hold to another on its exterior as they perform a spacewalk or use the International Space Station's controls. To build immersion, learners can hear the drone of cabin pressurization, see the high-quality graphical representations of Earth and outer space below them, and feel the weightlessness of microgravity through the touch controls of this astronaut simulation. Through these high-quality sensory inputs, the Mission: ISS eduVR experience elicits an emotional response from learners because it simulates the sights, sounds, and physics of living and working in space for learners.

HOW TO USE THIS RUBRIC

To demonstrate how to appropriately use this rubric, the following recommended workflow is offered to support reviewers:

1. Get to know the app: Before using the eduVR app, the reviewer should research the different functionalities and possibilities the app provides. Then, the reviewer should use the app to understand its operation and fully explore its content. With this background knowledge, the reviewer is prepared to move on to evaluating the app.
2. Start with Lee and Cherner's (2015) rubric: To begin, the reviewer should familiarize themselves with using Lee and Cherner's instructional app rubric. It is important to note that some of Lee and Cherner's dimensions may look slightly different in an eduVR app than in a more traditional app. For instance, A4. Value of Errors in eduVR may take the form of artificial intelligence which teaches by providing constructive feedback in virtual lab experiments based on learners' actions. Then, the reviewer would evaluate the app generally with the categories of (A) Instruction, (B) Design, and (C) Engagement using this rubric.
3. Evaluate the app's eduVR elements: Once the reviewer has evaluated the app generally, a deeper evaluation of the eduVR can begin. At this point, the reviewer would evaluate the eduVR app as a whole if the app itself is one eduVR experience or choose a desired eduVR experience from a library within the app. Then, the reviewer would evaluate the eduVR based on this rubric's categories of (D.) Positioning of the eduVR, (E.) Avatar Level, (F.) Virtual Environment, and (G.) Virtual Experience.

EXAMPLE EDUVR EVALUATION: WALTER'S CUBE – PABLO PICASSO

The above workflow will be shown in a review of the Walter's Cube (VR Space Holdings Inc., 2020) Pablo Picasso experience based on the exhibit at the National Museum in Warsaw. Walter's Cube (2020) allows art galleries and museums from all over the world to post their exhibits in VR. Learners can then explore these exhibits by moving their heads and touching their headset's buttons to walk in the direction they face. Learners can watch video and read more information about the pieces in the virtual environment. The full evaluation is provided in Table 3.

Table 3. Example evaluation using Lee and Cherner's (2015) rubric and the addendum

Rating from Lee and Cherner's (2015) instructional app rubric			Ratings from the addendum rubric (Appendix B)			
(A.) Instruction	(B.) Design	(C.) Engagement	(D.) Positioning of the EduVR	(E.) Avatar Level	(F.) Virtual Environment	(G.) Virtual Experience
A1. Rigor: 3 A2. 21st Century Skills: N/A A3. Connections to Future Learning: 2	B1. Ability to Save Progress: 3 B2. Integration: N/A B3. Screen Design: 5 B4. Ease of Use: 4	C1. Learner Control: 5 C2. Interactivity: 4 C3. Pace: 5 C4. Flexibility: 3 C5. Interest: 5	D1.Use of EduVR: 5 D2. Educational Impact: 3	E1. Avatar Representation: N/A E2. Interactions: N/A	F1. Authenticity and Realism: 4 F2. Content Presentation: 2 F3. Navigational Aids: 4	G1. Experiential Component: 3 G2. Pathways: 5 G3. Dimensionality of Movement: 4

Rating from Lee and Cherner's (2015) instructional app rubric			Ratings from the addendum rubric (Appendix B)			
A4. Value of Errors: N/A A5. Feedback to Teacher: N/A A6. Level of Materials: 3 A7. Cooperative Learning: N/A A8. Accommodation of Individual Differences: 3	B5. Navigation: 5 B6. Goal Orientation: 5 B7. Information Presentation: 5 B8. Cultural Sensitivity: 4	C6. Aesthetics: 5 C7. Utility: 4			F4. Multimedia Elements: 5	G4. Virtual Manipulatives: N/A G5. Control: 2 G6. Immersion: 3

CONTEXTUALIZING EDUVR

Virtual reality is becoming more commonplace in society. As a global community that is learning new ways to experience the world and work together, the implications for using eduVR are rich. This rubric provides stakeholders a tool they can use to assess the quality of eduVR experiences. As eduVR was already a well-funded and invested area within the edtech marketplace, the recent shift to "remote teaching" due to COVID-19 evidences a need for alternative modalities for delivering instruction. As technology and education continue to progress outside the traditional classroom model, flexible modalities for learning will become increasingly important. EduVR is potentially one of those modalities, and quality matters. If educators around the world are going to be asked to use eduVR to teach their students, they deserve the highest quality experiences. This rubric is the tool needed to evaluate eduVR for those educators.

RECOMMENDATIONS FOR USING THIS RUBRIC

The implications for using this rubric are robust. From using the rubric to informing the selection of eduVR experiences for the classroom to providing developers a guide for creating those experiences, the researchers identified four groups of people who can improve their work by using this rubric.

EDUCATOR SUPPORTS

First, while this rubric can serve educators by informing them about their choices on the types of eduVR they use in their classrooms, educators may not have the time required to use this rubric. Rather, the instructional coaches and entities who support educators can use it to vet and recommend eduVR experiences. Instructional coaches can use the rubric to analyze an eduVR experience and then determine if it meets their minimum criteria for recommending it to teachers. In addition, entities that provide searchable databases of educational technologies – App Ed Review (www.appedreview.com), Common Sense Media (www.commonsense.org/education), and EdShelf (www.edshelf.com) – can adopt this rubric to rate the eduVR experiences they include on their respective databases. These instructional coaches and entities who support educators can provide professional development and recommendations based on this rubric to effectively use eduVR.

Researchers

Second, this rubric provides researchers with a useful tool for selecting eduVR experiences for the classroom as well as monitoring the quality of eduVR being developed for classroom use. False claims about educational technologies are common (Matthewson & Burtymowicz, 2020), and eduVR experiences are no exception. This rubric provides a bridge to help ensure the eduVR experiences produced by developers and the design principles for high-quality eduVR experiences are aligned, and researchers are well positioned for that work. For example, researchers can identify a subset of eduVR experiences, including (1) EduVR for Field Trips, this group would consist of VR that takes students to visit places on earth, such as Switzerland or the Great Wall; (2) EduVR for Experiences, this group would provide learners with an opportunity they will likely not have, like riding in a space shuttle or being launched from a slingshot; and (3) EduVR for Interaction, this group would allow for learners to talk with one another or take part in a live lecture. Researchers then can evaluate a group to determine the highest quality eduVR experiences. Also, like instructional coaches, researchers can use this rubric to vet virtual reality experiences they would use in their studies. For instance, they may wish to measure eduVR experiences that rate in a certain way according to the rubric's dimensions. They can then use those eduVR experiences in their studies to determine the impact they have on student learning, engagement, and collaboration. Finally, researchers can monitor the virtual reality experiences being marketed for learning compared to entertainment, and they can use this rubric to analyze both sets of experiences followed by making implications for their findings. To explain, if virtual reality experiences for entertainment continually score higher or differently based on the rubric's dimensions compared to eduVR, what does that mean? Researchers can monitor those trends and note those implications.

EdTech Developers

Third, developers can use this rubric when meeting with their clients who are paying them to create eduVR. During those meetings, developers can use this rubric with their clients to explain the need for certain functionalities and elements within the experience. In fact, developers can even use this rubric as a more objective tool for determining the cost to buildout the functionalities and features within the eduVR experience. Then, when they are actively building the eduVR experience, developers can continue to reference this rubric to help ensure the experience they are creating meets the expectations of their client.

Edu-Philanthropists

Finally, edu-philanthropists are individuals who fund educational initiatives with direct donations or influence the direction of education at the state, national, and global stages using large grants (Cherner & Scott, 2019). Some of these edu-philanthropists are currently investing deeply in eduVR, and that is causing an explosion of it in the edtech marketplace. Researchers are yet to conclusively determine if there are benefits for using eduVR with students. However, the edu-philanthropists who are driving the investment in eduVR can use this rubric to help ensure that the experiences they do fund are of high quality. One way for them to help ensure that component is to directly reference this rubric along with Lee and Cherner's (2015) rubric in their requests for proposals.

Limitations

There are limiting factors that constrain this rubric's generalizability (Given, 2008), and these limitations largely include its design along with subjectivities that impact its applicability. These limitations will next be discussed in more detail.

Design Limitations

Virtual reality and technology at large are constantly progressing. Even though this rubric utilizes the least reckless of the futures models – probable futures – as its lens for preparing certain dimensions to stand the test of time, some aspects may not be extrapolated accurately using a lens based on our knowledge of current technology. To this end, there is the possibility that mobile eduVR may not progress along the same trajectory as desktop computer-based VR, or virtual reality functionalities currently under development may never make it to market. On the other hand, there may be advancements to mobile eduVR that we cannot even imagine in our current time. After all, inventors predicted mechanical horses before they imagined cars.

There may be budding facets of eduVR that this rubric overlooks. Functionalities of eduVR that are not prominent today, such as the integration of artificial intelligence, could justifiably be included in this rubric in the near future. However, there is simply not enough data on such uncommon functionalities in eduVR with which to extrapolate using the probable futures model. Although careful research, product testing, peer debriefing, and peer review were used throughout the development of this rubric, creating one rubric to encapsulate all eduVR experiences for mobile devices is a difficult task in our current age of rapid technological advancement.

The testing of this rubric includes a limited sample size. As the rubric is more widely disseminated, larger sample sizes with more diverse data can be used to improve its generalizability. Further testing in lockstep with technological advancement is needed in order to keep the rubric current and aligned to contemporary eduVR.

Impact of Subjectivities on Ratings

The subjectivities of evaluators are a limiting element for the usage of this rubric. This rubric is designed to quantify intrinsically subjective experiences. When using this rubric, evaluators must include their own judgements about the context of the eduVR experience and the learning content. Some eduVR experiences might reasonably not be designed to include all the rubric dimensions described above. Ratings of N/A should be ascribed to an experience in the situation where it is not designed for avatars or extensive travel that requires navigational aids, for example. Interpretations of each of the rubric's dimensions as well as indicators are reliant on evaluators understanding the rubric and the evaluation process as outlined in this article. Further, even if eduVR experiences score poorly in some areas of this rubric, it is up to evaluators to make personal decisions as to the appropriateness and viability of eduVR experiences for learning in their classrooms. Low-scoring eduVR experiences can still be used effectively based on contextual factors such as the level of learners, lesson material, lesson design, and integration strategies.

In addition, this rubric should not be generalized by the evaluator. As it is designed to evaluate a singular eduVR experience within a mobile app, the rating determined by the evaluator is specific to that eduVR experience. However, some mobile apps may include multiple different eduVR experiences with varying functionalities, like Oculus (Facebook Technologies, 2020) or Within (Within Unlimited, 2019). Others may include both virtual reality and augmented reality experiences within the same app, like LifeVR (TI Media Solutions, Inc., 2018) or Expeditions (Google LLC., 2020). Further still, some apps may include the ability for learners to switch between virtual reality and augmented reality modes within the same experience, like Bookful: Books for Kids (Inception XR Ltd, 2020) or Complete Anatomy (3D4Medical from Elsevier, 2020). Therefore, this rubric must be used mindfully by the evaluator and should not be used to (a) generalize a rating for an entire app based on a singular virtual reality experience or (b) evaluate another type of virtual experience, like augmented reality or extended reality.

Future Work

Subsequent research can bolster the validity of this rubric by collecting data from a diverse set of end users and stakeholders in three different ways. First, researchers can perform experimental studies to identify the most important elements of eduVR, using this rubric as a framework for their inquiry. Second, a large sample of students from different grade levels and abilities can be used to review eduVR experiences and provide feedback on the rubric's dimensions. Third, researchers can query educator supports, curriculum specialists, edtech developers, edu-philanthropists, among others, and refine the rubric levels based on their feedback.

There is an expanding need for instruments with which one can evaluate new educational technologies. While user experiences, functionalities, and learning possibilities between virtual, augmented, and extended realities exist on a continuum, they are inherently different in some areas. Therefore, an augmented reality accompaniment to Lee and Cherner's (2015) instructional app rubric is a logical next step for researchers. It is possible that virtual educational experiences of the future may follow a path toward extended reality, mixing virtual reality and augmented reality elements into a categorically different entity. As the direction of virtual experiences becomes clearer, the transcendent virtual reality and augmented reality evaluative domains can be merged and supplemented with new domains to create an instrument for the future.

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APPENDIX A

VALIDATION OF THE EDUVR RUBRIC FOR MOBILE APPS

Thank you for your willingness to critique our instrument. Your feedback will provide us with information about how we can better refine our instrument. Please provide your feedback using the following form.

Directions

Please review each of the following dimensions to determine how "concise" and "adequate" they are by rating them on a 5-point scale using the following breakdown:

5 = very good; 4 = good; 3 = average; 2 = below average; 1 = poor

Additionally, the "concise" rating focuses on how succinct and crisp the language used to describe the dimension is. The "adequate" rating determines if the language used satisfactorily describes the dimension's focus. Lastly, please provide any additional comments in the space following each dimension, especially if a rating of 1, 2, or 3 is assigned.

D1. Use of eduVR					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
D2. Educational Impact					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					

E1. Avatar Representation					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
E2. Interactions					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
F1. Authenticity and Realism					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					

F2. Content Presentation					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
F3. Navigational Aids					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
F4. Multimedia Elements					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					

G1. Experiential Component					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
G2. Pathways					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
G3. Dimensionality of Movement					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					

G4. Virtual Manipulatives					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
G5. Control					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					
G6. Immersion					
How concise is this dimension's question?	5	4	3	2	1
How adequate is this dimension's question?	5	4	3	2	1
How concise are this dimension's indicators?	5	4	3	2	1
How adequate is this dimension's indicators?	5	4	3	2	1
Additional Comment(s) and Suggestion(s):					

Final thoughts and reflections

APPENDIX B

EVALUATION RUBRIC FOR EDUVR IN MOBILE APPS

D. Positioning of the EduVR: The following dimensions analyze how the eduVR is situated based on the learning content.

D1. Use of eduVR: Is the eduVR experience appropriate for the content?

5	4	3	2	1	N/A
The eduVR meets the needs of the learner aligned to the content.	A mixture of eduVR and other technologies meets the needs of the learner aligned to the content.	A mixture of eduVR, other technologies, and the physical environment meets the needs of the learner aligned to the content.	Other technologies and the physical environment meet the needs of the learner aligned to the content.	The physical environment meets the needs of the learner aligned to the content.	Not Applicable

D2. Educational Impact: Where does the eduVR rank on the Substitution, Augmentation, Modification, and Redefinition (SAMR) scale?

5	4	3	2	1	N/A
The eduVR aligns to redefinition because the user experience is only possible in a digital context.	The eduVR aligns to modification because the user experience is only possible in extreme or rare instances.	The eduVR aligns to augmentation because it enhances a common user experience.	The eduVR aligns to substitution because it replicates a common user experience.	It would be more efficient to replace the eduVR with an analog experience.	Not Applicable

E. Avatar Level: The following dimensions analyze the look and interaction functionalities of the eduVR's avatars.

E1. Avatar Representation: How does the eduVR represent avatars?

5	4	3	2	1	N/A
The eduVR's avatar can be stylized and customized in great enough detail to appear lifelike.	The eduVR's avatar can be stylized and customized in great enough detail to appear mostly lifelike.	The eduVR's avatar's clothes and accessories can be customized, but not the body.	The eduVR includes multiple premade avatar choices that cannot be customized.	The eduVR includes only one premade avatar choice that cannot be customized.	Not Applicable

E2. Interactions: How does the eduVR provide for the users to interact with one another and in what ways (e.g., real-time conversation, file transfer, 3D modelling, collaborative actions, etc.)?

5	4	3	2	1	N/A
The eduVR provides users with multiple avatar-to-avatar interactions that are synchronous.	The eduVR provides users with few avatar-to-avatar interactions that are synchronous, but it may include more robust asynchronous interaction options.	The eduVR provides multiple user-to-user interactions that are asynchronous.	The eduVR provides few user-to-user interactions that are asynchronous.	The eduVR does not include user-to-user interactions.	Not Applicable

F. Virtual Environment: The following dimensions analyze elements of the eduVR's virtual environment.					
F1. Authenticity and Realism: Is the eduVR environment as authentic and real as possible?					
5	4	3	2	1	N/A
The eduVR provides a real-world environment or computer-generated environment in a way that is highly authentic and appropriately realistic, which enhances the user experience.	The eduVR provides a real-world environment or computer-generated environment that is authentic and does not enhance nor detract from the user experience.	The eduVR provides a real-world environment or computer-generated environment, but minor flaws exist with the authenticity of the environment that disturbs the user experience.	The eduVR provides a real-world environment or computer-generated environment, but major flaws exist within the authenticity of the environment that significantly disrupt the user the experience.	The eduVR does not provide a complete environment of any kind that is suitable for any type of user experience.	Not Applicable
F2. Content Presentation: How does the eduVR leverage multimodal elements (e.g., text, images, audio, video, etc.) and utilize active and passive strategies to engage users in the content?					
5	4	3	2	1	N/A
The eduVR combines multimodal elements along with active and passive strategies that utilize synchronous, person-to-person interaction to engage users in the content.	The eduVR combines multimodal elements along with active asynchronous strategies that do not include person-to-person interaction to engage users in the content.	The eduVR combines multimodal elements along with active and passive strategies to engage users in the content.	The eduVR combines multimodal elements but relies mostly on passive strategies to present users in the content.	The eduVR largely utilizes one element with passive strategies to present content to users.	Not Applicable
F3. Navigational Aids: Does the eduVR include indicators to aid navigation?					
5	4	3	2	1	N/A
The eduVR provides intuitive navigational aids that are logically placed to support users maneuvering through the environment at their own pace.	The eduVR provides navigational aids that are mostly intuitive and logically placed to support users maneuvering through the environment at their own pace.	The eduVR provides navigational aids that are intuitive to use but placed illogically, which limits the ease at which users can maneuver through the environment.	The eduVR provides few navigational aids that are not intuitive to use and illogically placed, which severely limits the ease at which users can maneuver through the environment.	The eduVR provides no navigational aids whatsoever and users must employ landmarks and trail-and-error strategy for maneuvering through the environment.	Not Applicable
F4. Multimedia Elements: How well does the eduVR integrate multimedia elements (e.g., text, graphics, videos, sound, live streaming, etc.) to engage users within the experience?					
5	4	3	2	1	N/A
The eduVR's multimedia elements are seamlessly integrated and organized in a way that enhances the user experience.	The eduVR's multimedia elements are integrated and organized in a way that does not enhance or detract from the user experience.	The eduVR's multimedia elements are well-integrated, but their organization detracts from the overall user experience.	The eduVR's multimedia elements are integrated and organized in a way that reduces the quality of the user experience.	The eduVR's multimedia elements are jumbled, confusing, and/or poorly organized, which significantly reduces the user experience.	Not Applicable

G. Virtual Experience: The following dimensions analyze the eduVR's virtual experience for users.					
G1. Experiential Component: How does the eduVR utilize experiential learning to engage users?					
5	4	3	2	1	N/A
The eduVR leverages experiential learning to engage users in tasks that require abstract logic and reasoning.	The eduVR includes an experiential learning component that provides users with added ability, access, or opportunity to complete tasks as compared to a similar concrete learning experience.	The eduVR provides an experiential learning component comparable to a similar concrete learning experience.	The eduVR includes an experiential learning component that provides users with less ability, access, or opportunity to complete tasks as compared to a similar concrete learning experience.	The eduVR could include an experiential learning component but does not.	Not Applicable
G2. Pathways: What pathways through the eduVR environment are available to users?					
5	4	3	2	1	N/A
The eduVR provides seemingly infinite pathways through the environment that users can navigate through at their own pace	The eduVR includes a set number of pathways through the environment that users can navigate through at their own pace within set parameters.	The eduVR only includes one pathway through the environment that users can move along at their own pace.	The eduVR only includes one pathway through the environment, and users are moved through it at a pace they do not control.	The eduVR only allows users to stand or be located in one place without any options for moving through the environment.	Not Applicable
G3. Dimensionality of Movement: Does the eduVR allow users to freely move around within the environment?					
5	4	3	2	1	N/A
Users have freedom of 3-dimensional movement (forward/backward, left/right, up/down) within the environment.	Users have freedom of 2-dimensional movement (forward/backward, left/right) within the environment.	Users have freedom of 1-dimensional movement (forward/backward) within the environment.	Users have a half-dimension of movement (forward) within the environment.	Users cannot move off a set point on a plane within the environment.	Not Applicable
G4. Virtual Manipulatives: Within the eduVR, how can users interact with virtual manipulatives (e.g. objects, tools, multimedia) in the environment?					
5	4	3	2	1	N/A
The eduVR allows users to move and share objects in 3 dimensions (e.g., pick up and toss a ball to another avatar).	The eduVR allows users to move objects in 3 dimensions (e.g., pick up a ball, spin it top to bottom or side to side).	The eduVR allows users to move and share objects in 2 dimensions (e.g., hit an air hockey puck back/forth, left/right against each other).	The eduVR allows users to move objects in 2 dimensions (e.g., moving a pencil left/right, up/down).	The eduVR allows users to interact with objects in 1 dimension (e.g., pressing a button in).	Not Applicable

G5. Control: Within the eduVR, to what extent can users control their movement, manipulation, and dexterity?					
5	4	3	2	1	N/A
Users' movement, manipulation, and dexterity in the eduVR can be controlled by body movements in addition to hand motions, finger motions, physical controllers, button selection, and head movement.	Users' movement, manipulation, and dexterity in the eduVR can be controlled by hand and finger motions in addition to physical controllers, button selection, and head movement.	Users' movement, manipulation, and dexterity in the eduVR can be controlled by fists with physical controllers along with button selection, and head movement.	Users' movement, manipulation, and dexterity in the eduVR can be controlled by button selection on a headset along with head movement.	Users' movement and manipulation in the eduVR can be controlled by focused gaze interaction through head movement only.	Not Applicable
G6. Immersion: How immersive is the eduVR to the user?					
5	4	3	2	1	N/A
The eduVR stimulates many of the users' senses to create a completely interactive experience that results in them making an emotional investment in the experience and blurring their physical and virtual worlds.	The eduVR stimulates the users' senses to create an interactive experience but lacks a strong enough emotional appeal needed for users to blur their physical and virtual worlds.	The eduVR only stimulates some of the users' senses, which precludes the experience from being interactive or emotional.	The eduVR allows users to interact with space, trigger events, or engage with manipulatives, but little else.	The eduVR only consists of a 360° environment that does not allow for user interaction outside of viewing the content.	Not Applicable

AUTHOR INFORMATION

Dr. Alex Fegely is an Assistant Professor of Instructional Technology at Coastal Carolina University. Previously, he was a university lecturer, a social studies and digital media teacher in South Carolina, a web developer, and a graphic designer. His most recent scholarship has focused on computer science education, diversity in edtech, and the use of XR in education.

Dr. Todd Cherner is the Director of the Master of Arts in Educational Innovation, Technology, and Entrepreneurship at the University of North Carolina at Chapel Hill. Cherner specializes in using technology to promote informed citizenry and critical literacy. Cherner started his career as a high school English teacher in Florida before becoming a professor. As he gained experience working with teachers in both secondary and higher educational settings, he has honed his skills for identifying edtech that can be used for supporting student learning, collaboration, and engagement.