

# Mixed-Reality Learning Environments in Teacher Education: An Analysis of TeachLivE™ Research

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## Abstract

TeachLivE™, a mixed-reality simulated classroom technology, has been used in initial teacher education programs to provide repeatable experiential learning opportunities for students now for more than a decade and in more than 80 universities worldwide. However, no broad scale investigation has been conducted into how the platform has been used or what research has been generated as a result. The aim of this study is to provide insight into the types of TeachLivE™ research carried out since its inception and to identify trends and potential gaps in this research. Peer-reviewed academic primary research publications—journal articles (23), conference proceedings (12), and thesis dissertations (20)—were reviewed for participants, research methods, analysis, research design, data collection tools, and design approaches. Of the 102 articles identified as relevant, “instructional skills development” and “integration of TeachLivE™ in teacher education” were the most commonly researched topics. Findings indicate that preservice teachers were the most commonly studied group of participants, research methods were predominately qualitative, single-subject experimental research design was employed most often, and the most used data collection tools were surveys and observation. These findings highlight that the range of topics is increasing, with studies on in-service teachers in school-based contexts beginning to emerge as a new area of interest. This systematic review has implications for researchers and the developers of TeachLivE™. It provides valuable insight and recommendations for future studies in this emerging teacher education field, where technology is not simply used “in the classroom” but rather “as the classroom.”

## Keywords

TeachLivE™, mixed-reality learning environments, systematic analysis, initial teacher education, teaching with avatars

## Introduction

Although many research studies have been conducted on the use of virtual reality simulations in education contexts in recent times, gaps persist in understanding how virtual learning environments contribute to preservice teacher learning outcomes and how this technology is being applied in initial teacher education programs (Billingsley et al., 2019; Martin-Gutierrez et al., 2017). Thus, the increased integration of mixed-reality simulated classroom technologies, such as TeachLivE™, into initial teacher education programs necessitates, as a matter of urgency, that current research is reviewed, research outcomes synthesized, and potential benefits and limitations are identified (Templier & Paré, 2015). A comprehensive standalone review of literature, therefore, has the potential to provide independent information to initial teacher education program providers on the efficacy of the platform, and to inform future empirical studies (Jesson et al., 2011). As a broad standalone review of published TeachLivE™ literature, it will seek to inform initial teacher

education program development, facilitate development of theory, synthesize existing literature, reveal seminal texts in the field, and has the potential to become a milestone paper in the published use of TeachLivE™ in education contexts (Paré, 2015).

Research into the use of TeachLivE™ has focused on a broad range of topics, including how this mixed-reality simulation technology has been integrated into initial teacher education programs. Research suggests that a controlled TeachLivE™ experience, directed by university educators, can provide safe, constant, and predictable classroom

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scenario experiences for preservice teachers. These unique benefits are in direct contrast to the unpredictable live contexts typical of school-based professional experience placements. Increased understanding of the efficacy of such integration has the potential to address ongoing scrutiny by government reform enquiries of initial teacher education providers to increase the efficacy of their programs (Fitzgerald & Knipe, 2016; Loudon, 2008), particularly in the area of provision of adequate practical teaching experience. Recognized as a crucial aspect of initial teacher education programs (Darling-Hammond, 2006) practicum placements require considerable organizational effort and financial outlay, while at the same time needing to address the constant concern of inconsistent experiences being provided to preservice teachers (Tindall-Ford et al., 2017). Alternative methods have been employed, trialed, and reported over the last century to better prepare graduates for professional placements and for the rigors of the teaching profession itself (Ledger & Fischetti, 2020). Thus, published research provides insight into how TeachLivE™ can contribute to the quality of teacher education and to the preparedness of preservice teachers in relation to the demands of real-life classroom settings.

According to Grant and Booth (2009), a systematic review of literature is designed to “systematically search for, appraise and synthesise research evidence” (p. 102). This type of review was considered the most suitable method to summarize and synthesize TeachLivE™ published research. This article used a focused research question and a comprehensive and reproducible search strategy to collect and analyze data to present an unbiased summary of findings. Specifically, this article presents insight into the research trends, gaps, and areas requiring development related to the integration of the TeachLivE™ platform into initial teacher education programs during a key period of early adoption during 2012–2017 inclusive. This review will also identify topics not yet covered by current TeachLivE™ published research.

Research in the field of initial teacher education highlights a range of specific programs and approaches but tends not to focus on the foundational learning theories that underpin effective design and development of immersive technologies products (Fowler, 2015). The following review of literature highlights a range of current virtual learning environments being explored for educational purposes that highlight this anomaly.

## Literature Review

### *Immersive Learning Environments in Initial Teacher Education*

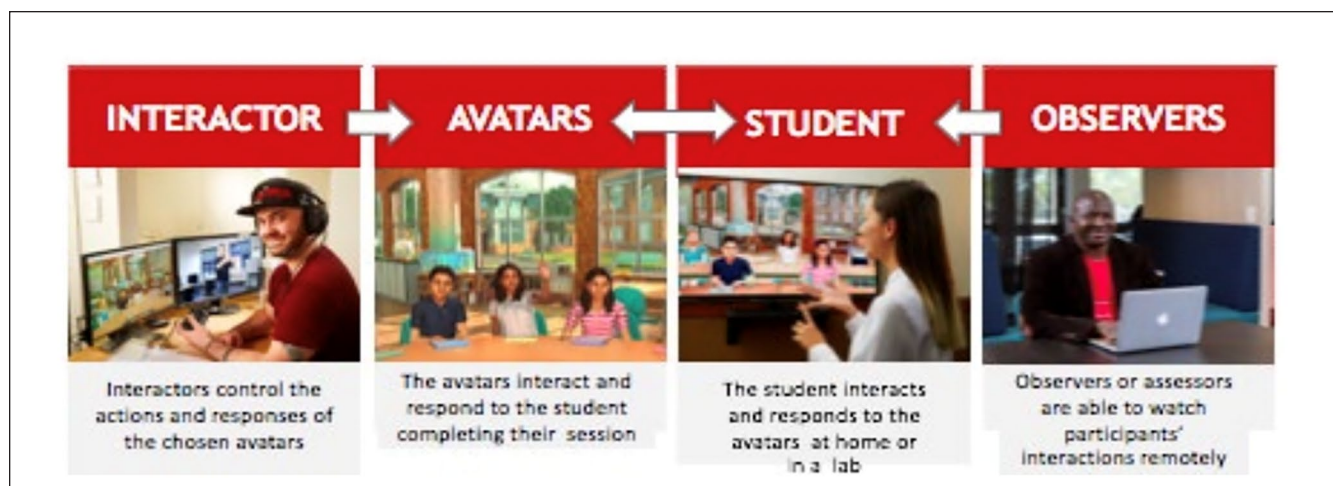
The rapid rate of technological change in devices, software, and virtual learning environments places pressure on teacher educators to continually explore how emerging digital

platforms can augment student learning outcomes. Learning technologies have now progressed from a simple tool to be used “within the classroom” to immersive platforms that can be used “as the classroom.” Dede et al. (2017) suggested that most immersive technologies fit into three broad typologies: Virtual Reality (VR); Multi-User Virtual Environments (MUVE); and Mixed-Reality (MR), with each interface having benefits and challenges and creative potential for educational contexts.

VR is typically described from two perspectives, technological and psychological (Coelho et al., 2006). VR can be described as a collection of diverse technologies with interactive means, which psychologically and physically immerse learners in a simulated learning environment. The use of virtual simulations is limited in teacher education practices (Hughes et al., 2005). However, in the last decade, simulated learning environments, artificial intelligence, and immersive technologies have gained considerable attention by educational researchers. To date, several virtual simulation environments are being used with growing success in teacher education (Dede et al., 2017).

Online programs and software such as SimClass, Secondlife, and artificial intelligence, each with their particular strengths and weaknesses, are also being used to prepare graduates (Aten Intelligent Educational Systems Inc, 2015; Gibson et al., 2011; Girod & Girod, 2006). TeachLivE™ differs from these in that it is not dependent on “real” classrooms or teachers, nor is it asynchronous in its technological design and implementation. As a relatively recent technology, TeachLivE™ has a synchronous human-in-the-loop feature within the simulation that provides real-time responses to individuals or cohorts of preservice teachers. TeachLivE™ is suggested by its creators, the University of Central Florida, as a tool that develops the art and skill of teaching in a mixed-reality classroom learning environment.

In initial teacher education, a range of virtual reality simulations are commonly used. Bradley and Kendall (2014) categorizes the virtual reality simulations into three groups based on their categories: Virtual Puppetry Simulations, Multi-User Virtual Simulations (MUVEs), and Single User Simulations. Teacher Talk Game (Simiosys, 2014) and TeachLivE™ (Dieker et al., 2014) are classified as synchronous mixed-reality virtual puppetry. In contrast, Sim School (Gibson et al., 2011), Classroom Sim (Aha!, Process Inc., 2012), At Risk for High School Educators (Kognito Interactive, 2012), At risk for Middle School Educators (Kognito Interactive, 2012), and Step In, Speak Up! (Kognito Interactive, 2012) are classified as asynchronous single user simulations which have pre-programmed responses to interaction between Preservice Teachers (PSTs) and the simulated student (p. 7). Cook School District simulation, and Teacher Work Sample Methodology (Girod & Girod, 2006) simulations are also commonly used in teacher education as single user mixed-reality tools. TeacherSim, Active World, and Second Life are classified as multi-user



**Figure 1.** Components of SimLab HITL simulation at Murdoch University (Ledger, 2017).

virtual reality environments, providing experiences similar to those of professionals in their daily work life, along with opportunities to engage with peers and experts in a collaborative learning environment. Each virtual simulation has its own unique purpose in developing preservice teachers' toolkit of skills, knowledge, and dispositions.

### *The TeachLivE™ Mixed-Reality Simulated Classroom*

TeachLivE™ provides a synchronous mixed-reality learning environment involving virtual puppetry and targeting preservice and in-service teachers (Dieker et al., 2014). TeachLivE™ was first conceptualized at the University of Central Florida in 2005. The College of Education and the College of Engineering and Computer Science collaborated to investigate the use of blending human and avatar interactions to impact teacher practice (Dieker, Straub, et al., 2014). The current system is currently being used in over 80 universities across America, Europe, United Arab Emirates, Malaysia, and more recently in Australia at Murdoch University, The University of Western Australia and University of Newcastle.

As previously mentioned, TeachLivE™ is different from other simulations due to the synchronous nature of the mixed-reality learning environment. It consists of a combination of computing, puppeteering, professional actors, and artificial intelligence. The unique human in the loop system enables the avatars to perform a set of behaviors that are similar to a typical student or students with learning difficulties (Dieker, Rodriguez, et al., 2014). The human looped system relies on interactors (puppeteers) to control the avatars in a manner similar to puppeteering or computer gaming techniques. The interactors control the avatars remotely allowing students to access the platform from anywhere via a video conferencing platform such as Skype or Zoom.

The human in the loop system offers synchronous responses to student teachers which adds to the illusion that the avatars are responding independently (Ledger, 2021; Avatar Mediated Interactive Training-AMITIES; Hughes et al., 2015; Nagendran et al., 2013). The simulation also provides the preservice teacher with opportunities for immediate feedback and coaching by a teacher educator overseeing the process.

The simulated classroom environment relies on three interrelated elements. First, the interactor is located in a "SimStation" and is able to view participants located in another room or remote location. This direct viewing enables synchronous responses between interactor and participant (Dieker et al., 2016). Second, the teacher views the avatars via a large screen in the "SimLab" or on their own device via Skype or Zoom. Third, the technical assistant/teacher educator is located in the lab and is able to view the participants and their engagement with the avatars (Figure 1). Each simulated engagement is videotaped and critiqued by the technical assistant/teacher educator. Feedback opportunities exist during the simulated teaching experience (online) and at the conclusion of the session (face-to-face or online).

### *Research on TeachLivE™*

TeachLivE™ has been expanded across initial teacher education programs across the globe with associated literature emerging including a large body of research generated by the original research team from the University of Central Florida (UCF). A 3-year project funded by Bill & Melinda Gates Foundation generated the first report on the innovative platform addressing annual aims and milestones. In the first year, they determined TeachLivE™ simulator effect on Mathematics teachers' performance (Straub et al., 2014). The second year focused on TeachLivE™ simulation effect

on Science teachers' performances (Straub et al., 2015). The third year aimed to identify the efficacy and evolution of TeachLivE™ for commercialization and how the simulator meets the needs of school administrators and teachers of inclusive classrooms (Hynes et al., 2016). The findings from the studies generated from the project centered on computer simulation, synchronous online instruction, and lesson resources. Results from Phase 1 showed that TeachLivE™ simulations could be useful in impacting teacher practice and that four 10-minute sessions in the TeachLivE™ simulator improved targeted teaching behaviors (Gates National Research Report, 2015). Findings from Phase 2 revealed that TeachLivE™ simulations could be effective in professional learning (Gates National Research Report, 2015). In the third year (Phase III), the team used the results obtained from the first and second year and examined the participants' experiences in a qualitative paradigm (Betch & Delisio, 2015). Teachers reported positive perceptions related to the authenticity, interactivity, and individualization of PD in the TeachLivE™ (Gates National Research Report, 2016).

Additional research studies emerged from the original research team in the third year of the funded program as outlined in the Gates National Research Report in 2016 (Dieker et al., 2016). These are summarized below.

1. Research related to the development of micro-credentials concerning behavior management techniques such as Positive Praise and co-teaching found an improvement in the use of praise, but data analysis did not produce significance.
2. Education Testing Services (ETS) partnered Mursion™ during this time and conducted their own research to develop training protocols and initial licensure testing for teachers. A summary of the informal results outlined in the report highlighted particular needs of pre-service teachers in regard to asking high order questions and fraction concepts.
3. Research on culturally responsive skills development using TeachLivE™ is yet to be completed.
4. Research using TeachLivE™ simulation to facilitate counselor educator as a professional development tool found that the simulation training did not affect the improvement of basic counseling skills, counselor self-efficacy, and anxiety.
5. Peer tutoring was explored using TeachLivE™. Elementary-aged students did one-to-one tutoring to an avatar. Results found TeachLivE™ simulations positive for clinician's interpretations, presence, and academic experience.
6. Beyond Z, a non-profit training organization that develops necessary skill sets for experts and leaders used TeachLivE™ simulations to see if it facilitated faster learning, skill development, and maintenance of professional skills. Findings revealed TeachLivE™

attended to some of the skills but could not determine if the simulation was efficient in developing the complete professional skills set.

7. Research on adult problem-solving skills in the workplace using TeachLivE™ is yet to be finalized.
8. The final study investigates the training of a social skills package for adolescents with autism spectrum disorder. Results revealed that all participants increased their skills in at least one of the social behaviors (Gates National Research Report, 2016).

While TeachLivE™ researchers at UCF focused on mathematics and science teacher's skills, the research team developed a reflective observation tool called *After Action Review* (AAR). The video-tagging software included with the simulation records all the sessions and compresses the video recording to a smaller format to store them easily on a computer. The metrics could also be used to assess the number of questions and feedback used by participants (Gates National Research Report, 2014). In the second year, the AAR tool developed into a more sophisticated version aptly labeled *ReflectivE*. Analytics were collected during each session automatically gathering data related to student talk time and interactions (Gates National Research Report, 2015). At this stage, *ReflectivE* analytics remains a UCF initiative and has not been absorbed by Mursion, the commercialization collaborative partner.

Although TeachLivE™ was initially established to attend to the needs of preservice teachers, strong interest from the fields of hospitality, leadership, counselors, special needs, public speaking and work readiness (Dieker et al., 2016). As the program grows and more universities are adopting TeachLivE™, additional research is emerging that is not generated by the original TeachLivE™ research team. A brief summary shows that over 102 publications including journal articles, thesis dissertations, and conference proceedings have been published at the time of this investigation. These texts provide the data set for the following systematic review.

The following systematic review provides an analysis of literature on the mixed-reality learning environment called TeachLivE™. Data were examined from published peer-reviewed journal articles, conferences both specific to TeachLivE™ and others, along with theses and dissertations. The purpose of the study is to scope the literature on this emerging technology, to support future research endeavors, and to inform the developers of initial teacher education programs about the trends, gaps, and possible areas requiring development.

## Method

This article follows Kitchenham and Charters (2007) six fundamental steps to conducting systematic literature reviews: (1) identify the purpose of the review and research questions; (2) conduct a literature search to identify range and scope of

the review; (3) screen for inclusion; (4) assess quality; (5) extract data; and (6) analyze and synthesize data. This review is also underpinned by three key reflective dimensions of rigor, relevance, and methodological coherence that exist between the six components of the review (Paré et al., 2015). This was addressed during each phase of the process through triangulation of results generated after the analysis of data.

### Research Question

The following question guided this research: “What are the research trends and gaps in TeachLivE™ research?”

Seven research subquestions provided the framework and structure for the search methods and analytic framework, and guided this systematic review:

- a. How has the number of TeachLivE™ research publications (theses and dissertations, journal articles and conference proceedings) changed over the years?
- b. What is the range of topics commonly studied in TeachLivE™ research?
- c. What participants are commonly used in TeachLivE™ research?
- d. What methods are commonly used in TeachLivE™ research?
- e. What data tools are commonly used in TeachLivE™ research?
- f. What gaps were revealed from these studies focused on TeachLivE™?
- g. What inferences could be made for future research in TeachLivE™ research?

### Selection of Publications

Systematic review protocols have been used to identify inclusion and exclusions. The following criteria were taken into consideration in the selection of the publications:

1. All the publications must be written in English.
2. Peer-reviewed (journal, full text conference proceedings and thesis) publications beginning in 2012, TeachLivE™ inception.
3. We searched “Google Scholar” to find publications starting from 2012. We searched through “Google Scholar” because it covers many databases including “Springer,” “IEEE Explorer,” “Wiley Online Library,” “JSTOR,” “ERIC,” “Questia” and University libraries. Additional databases such as “PsycINFO,” “Web of Science” and “Scopus” were searched.
4. We searched TeachLivE™ website (<https://sites.google.com/view/teachlive/home>) to find “TeachLivE™ Conference Proceedings” from 2012 and separated conferences by TeachLivE™ conference proceedings and others.

5. “TeachLivE™,” “mixed-reality classroom with simulated students” and “Immersive Rehearsal Environment” used as keywords for all searches.

### Data Analysis

All publications, including journal articles, thesis dissertations, and conference proceedings, identified as meeting the criteria for the review were analyzed to explore the impact of TeachLivE™ simulations on teacher education and to identify research gaps and trends emerging from TeachLivE™ research.

This systematic review used evaluation criteria based on author, publication year, research methods, research topics, participants, and data tools from each study to produce results in the form of frequency analyses (Bandara et al., 2011). For data analysis purposes, we categorized the findings using the following codes and categorizations: author; year and topic of research from 2012; participants; research methods; analysis of methods; research design; data tools and adapted design approaches. Findings were classified into topics.

Two researchers classified each publication into one best-fit category, considering the publications overall among the categories created for each criterion. The end of the categorization process resulted in an agreement of 0.92. These researchers reached consensus after discussing and resolving any disagreements. An Excel data sheet was used to capture, analyze, and visualize the data. Descriptive statistics including frequencies and percentages were used to analyze the data. The findings were presented to reveal results from each of the categories and subsequently critiqued to reveal research trends and gaps in TeachLivE™ research.

**Categorization of topics.** Categories were defined based on the core aims of the publications. Overall, 25 general categories were identified, including classroom management skills development; instructional skills development; counseling skills development; preventing bullying behaviors skills development; interview skills development; social and physical presence skills development; efficacy beliefs development; workplace problem-solving skills development; reinforcement language skills development; gesture utility improvement; educational leadership skills development; fidelity implementation skills development; coaching skills for teacher development; integrating TeachLivE™ in teacher education; integrating TeachLivE™ in law enforcement education; trifecta model; reducing behavior problems among youth with autism; addressing preconceptions in a subject; assessing anxiety levels; functional analysis; social interactions of children with autism; preparing teachers for diverse learners; readiness for family engagement; and mentoring skills and assessment of teaching behavior.

**Table 1.** The Results of Analysis of Topics in Journal Articles on TeachLivE™ by Publication Year.

Topics	2012	2013	2014	2015	2016	2017	Total
Assessment of teaching behavior						1	1
Classroom management skills development		1			2		3
Clinical coaching	1				1		2
Counseling skills development						1	1
Educational leadership skills development				1			1
Efficacy beliefs development				1	1		2
Reinforcement language skills development		1				1	2
Instructional skills development					1		1
Integrating TeachLivE™ in teacher Education			3	1	3		7
Interview skills development					2		2
Reducing behavior problems among youth with autism					1		1
Total	1	2	3	3	11	3	23

**Categorization of participants.** We also categorized the participants regarding the content of those studies as “special education,” “pre-service teacher education,” “in-service teacher development,” “counselling students’ development,” “educational leadership students’ development,” “employees,” “students with autism,” “adults with intellectual disabilities,” “law personnel,” “adolescents with autism,” and “university teaching assistants.

**Categorization of methods.** Research methods were categorized as follows: (a) experimental design including “multiple baseline across participants,” “multiple baseline across target skills,” “multiple elements design or alternating treatment design,” “multiple probe design,” “experimental group design,” “A reversal design (A-B-A-B)” and “quasi experimental design”; (b) Quantitative methods which includes “surveys,” “questionnaires” and “quantification of observations results”; (c) Qualitative methods which includes “reflections,” “observations,” “semi-structured questions,” “interviews,” “case studies,” “feedbacks” and “group discussions”; (d) mixed methods which include both qualitative reflections, responds to questions and surveys, questionnaires.

**Categorization of data tools.** The data tools were categorized as “video data coding” “observation checklists or forms,” “focus group or group discussion,” “surveys,” “questionnaires,” “interview rating forms,” “rubrics,” “questions,” After Action Review Tool (AAR), “Rating scales,” and “body tracking tools.”

## Results

In total, 102 publications were identified for review. These publications included 23 journal articles, 20 thesis dissertations, 12 conference proceedings, and 47 TeachLivE™ conference proceedings beginning 2012. The publications were analyzed in terms of concepts/topics, participants, methods,

and data tools. Below, all publication types are presented in detail under their categories.

### Results for Journal Articles

The 23 journal articles were analyzed to find the research trends in TeachLivE™ studies since 2012. The results showed an increasing number of papers being produced in the field, ranging from 1 to 11 in 2017.

The most common studied research topic focused on integrating TeachLivE™ within teacher education ( $n = 7$ , 30%), followed by classroom management skill development ( $n = 3$ , 13%), clinical coaching ( $n = 2$ , 8%), efficacy beliefs ( $n = 2$ , 8%), interview skills development ( $n = 2$ , 8%), and reinforcing language skills development ( $n = 2$ , 8%). About 47% of all publications were done in 2016.

Table 1 shows that the research studies are mostly conducted for preservice teacher’s skills development ( $n = 13$ , 56%) following preservice special education teacher’s development ( $n = 3$ , 13%). The experimental design which includes single-subject designs as multiple baseline, probe, element or alternating designs, group designs and quasi-experimental designs ( $n = 10$ , 43%) were most commonly used methods in the journal articles following by the theoretical papers ( $n = 6$ , 26%) and the mixed method designs ( $n = 5$ , 21%) (see Table 2 in the Online Appendix). TeachLivE™ original projects were mostly focused on experimental design, quantitative and qualitative methods (Bill and Melinda Gates Final Report, 2016; Gates National Research Report, 2014, 2015, 2016).

Surveys and observation tools were the most commonly used data tool in the journal articles. Table 3 (see the Online Appendix) shows the range of different data tools used in TeachLivE™ research studies. The most frequently used include “survey” ( $n = 7$ , 41%) following by “observation” ( $n = 5$ , 29%), “video data coding” ( $n = 4$ , 23%), “reflection” ( $n = 2$ , 11%), “AAR” ( $n = 2$ , 11%), “interview” ( $n = 2$ , 11%), “rating scales” ( $n = 1$ , 5%), and “rubric” ( $n = 1$ , 5%).

## Results for Thesis Dissertations

The results for analysis by year are as follows: Total number of thesis/dissertations on TeachLivE™ include two master's and 18 doctorates ( $n = 20$ ). The distribution of doctorate dissertations on TeachLivE™ included one in 2017, five in 2016, two in 2015, five in 2014, one in 2013, and four in 2012. In 2017, the number was reduced due to the timing of this study; however, from 2012 to 2016, thesis completions increased. The number of master's thesis was low compared with the number of doctorate dissertations.

The most frequent topics for thesis dissertations were "instructional skills development" ( $n = 5$ ), "coaching skills for teacher development" ( $n = 2$ ), and "reinforcement language skills development" ( $n = 2$ ) (see Table 4 in the Online Appendix). The number of dissertations each year shows different trends. Reasons for this may be that pursuing a doctorate takes time and some research has already conducted on TeachLivE™ could be continuing. It has been 6 years since the TeachLivE™ initiated and so far, 20 master's and doctorate thesis completions. This shows that TeachLivE™ continues to attract researcher's attention from around the globe.

Of the 20 theses, TeachLivE™ researchers preferred to use experimental designs ( $n = 14$ ) (see Table 5 in the Online Appendix). Within these 14 thesis and dissertations that conducted experimental design models: experimental group design ( $n = 2$ ), multiple baseline design across participants ( $n = 5$ ), alternating treatment design/multiple element design ( $n = 2$ ), multiple baseline design across target skills ( $n = 1$ ), multiple element design ( $n = 1$ ), multiple probe design ( $n = 1$ ), and quasi-experimental design ( $n = 2$ ).

Due to the nature of TeachLivE™, the data tool set of experimental design seems best to explore the benefits of virtual simulations in gaining competences. While eight of the studies were based on the preservice teacher's abilities, four of them were on preservice special education teachers, and two of them were on in-service teachers. We can conclude that most of the studies were about teaching skills and targeted the teaching staff.

Following by interviews ( $n = 4$ , 20%), rubrics ( $n = 3$ , 15%), video data coding ( $n = 2$ , 10%), case study ( $n = 2$ , 10%), the Surveys ( $n = 6$ , 30%), and Observations ( $n = 6$ , 30%) was the most commonly used data tool in thesis and dissertations.

## Results for Conference Proceeding

The number of conference proceedings according to years included 2017 ( $n = 1$ ), 2016 ( $n = 2$ ), 2015 ( $n = 3$ ), 2014 ( $n = 5$ ), 2013 ( $n = 1$ ), and 2012 ( $n = 1$ ). When comparing the number of proceedings by years, 2014 was the most published year ( $n = 5$ , 38%) (see Table 7 in the Online Appendix).

While "integrating TeachLivE™ in teacher education" was most commonly researched ( $n = 5$ , 38%) following by "gesture utility improvement" ( $n = 3$ , 23%), "instructional

skills development," "integration TeachLivE™ in law enforcement education," "assessment of teaching behavior," "classroom management skills," and "trifecta model" were the rarely studied the ones that just one time done by the researchers when the conference proceedings analyzed (see Table 5 in the Online Appendix).

The research methodology used by the papers published in conference books were commonly based on theoretical papers ( $n = 4$ , 31%), following by experimental design ( $n = 2$ , 15%), multiple element design ( $n = 1$ , 8%), mixed method ( $n = 1$ , 8%), and quantitative method ( $n = 1$ , 8%). Interestingly, the number of theoretical papers was higher than the other types of research. Most commonly, they have been published in 2014 which is still in early phases of TeachLivE™ research so most of the papers could be aimed to introduce and explore how TeachLivE™ could be used in teacher education or other areas. Surely, the best place to share academic ideas was conferences.

Except for theoretical papers ( $n = 7$ , 54%), in conference proceedings researchers preferred to use video data coding ( $n = 2$ , 15%) and surveys ( $n = 2$ , 15%) following by AAR, reflection, body tracking, and observations (see Table 8 in the Online Appendix). The researchers also commonly preferred to work with preservice teachers ( $n = 5$ , 38%), preservice special education teachers ( $n = 3$ , 23%), and in-service teachers ( $n = 3$ , 23%). The other participants such as adults and law personnel were in a low percentage of preferred participants ( $n = 1$ , 8%).

## Results for TeachLivE™ Conference Proceedings

Since 2013, the TeachLivE™ conferences have been held every year. The number of proceedings as following related to years that they have been published: eight in 2017, seven in 2016, nine in 2015, eleven in 2014, and twelve in 2013. To date, 47 proceedings have been presented in TeachLivE™ conferences, and they have been published in conference book as full texts. In Table 6 (see the Online Appendix), we summarized the analysis of topics presented in TeachLivE™ conferences between 2013 and 2017. The most commonly studied topic was "integrating TeachLivE™ in teacher education" ( $n = 14$ , 29%), most of them was done in 2013 ( $n = 6$ ) and 2017 ( $n = 4$ ), following by "instructional skills development" ( $n = 11$ , 23%), most of them were done in 2015 ( $n = 5$ ) and 2013 ( $n = 4$ ). The "clinical coaching skills" ( $n = 3$ , 6%), "educational leadership skills" ( $n = 2$ , 4%), "functional analysis" ( $n = 2$ , 4%), "interview skills development" ( $n = 2$ , 4%), "preparing teachers for diverse learners" ( $n = 2$ , 4%), and "social and physical presence skills" ( $n = 2$ , 4%) were less studied in TeachLivE™ conference proceedings (see Table 9 in the Online Appendix).

The most commonly studied topic was the integration of TeachLivE™ into teacher education and instructional skills development. The TeachLivE™ Year 1 and Year 2 reports

showed a positive simulation impact on skills development in teacher education (Gates National Research Report, 2014, 2015).

Qualitative research methods were most commonly utilized in TeachLivE publications ( $n = 19$ , 40%), followed by experimental designs (total  $n = 11$ , 23%) including group design ( $n = 4$ , 8%), a reversal design ( $n = 1$ , 2%), alternating treatment design ( $n = 1$ , 2%), multiple baseline design ( $n = 2$ , 4%), and quasi-experimental design (3, 6%). There were also theoretical papers ( $n = 9$ , 19%), mixed method papers ( $n = 6$ , 13%), and quantitative papers ( $n = 2$ , 4%) published in TeachLivE™ conference proceedings.

## Discussion and Conclusion

This systematic review has compiled empirical evidence to map bodies of literature and draw conclusions regarding research trends and gaps in TeachLivE™ research. TeachLivE™ has proven itself to be a genuine alternative for better preparing preservice teachers for real-life classroom contexts. The study highlights the benefit of TeachLivE™, a mixed-reality virtual learning environment within the literature. It provides preservice teachers a platform to practice and rehearse the art and skill of teaching within a controlled simulation setting using synchronous avatars. This study sought to analyze and review the literature currently available on TeachLivE™ studies since its research inception in 2012. We examined 102 publications according to publication types, topics, methodology, data tools, participants, and findings. The results and findings revealed above provide a comprehensive baseline data set on TeachLivE™ publications and highlights current trends and gaps.

The study found that TeachLivE™ is drawing much interest, particularly given the increased uptake of the tool in over 75 universities around the globe. The research highlights common topics, methods, participants, and analysis tools within the data set. The findings show that the range of topics are increasing in scope but are predominately focused on the integration of TeachLivE™ in teacher education and instructional skill development. Most TeachLivE research examines preservice teacher's skill development and preservice special education teacher's development. This finding aligns with the original conceptualization of TeachLivE™ which aimed to use technology to improve teacher education programs by strengthening and improving the self-efficacy of students (Kaufman & Ireland, 2016).

In summary, participants within TeachLivE™ research continues to focus on preservice teachers; however, studies are emerging that focus on in-service teachers, and the benefit of simulation is being realized within school-based contexts. This finding is supported by research that proves the efficiency of using virtual simulations to better prepare teachers to their future career (Ledger & Fischetti, 2020; Billingsley et al., 2019). The range of methods is changing

over time but still, they are mostly based on qualitative, experimental single-subject design and theoretical reviews. The research profile in teacher education field on using virtual simulations as a tool mostly focuses on experimental design (Kaufman, 2019). The range of data tools commonly used in the TeachLivE™ research were surveys and observations and video recordings in TeachLivE™.

The authors call for more research within the identified gaps related to TeachLivE™: reflective practice, classroom management skills, lesson objectives, assessment, and self-determination theory. Most studies were used in cognitive level skill development and mastery. Future possibilities and recommendations for researchers include attending to the research gaps, building on current research trends, and exploring ways that will generate large scale research. The development of TeachLivE™ as a tool to identify strengths and weaknesses of preservice teachers using self-determination theory, self-efficacy, and the transferability of skills is one such area of future research. Linking TeachLivE™ to teacher professional standards is another way of monitoring TeachLivE™ and its effectiveness in better preparing future teachers.

Reflective practice is essential in any learning environment, particularly in the preparation of teachers. Jennifer Gore (2015) and Ersozlu (2013) suggest that good teachers continually consider the quality of their work; John Dewey stated, "We do not learn from experience. We learn from reflecting on experience" (Dewey, 1933, p. 78). TeachLivE™ and its combination of avatars and virtual simulations facilitate the reflective cycle and allow the participants to observe and reflect on their actions or others' re-actions.

## Limitations and Future Research

Findings of this study are limited to publications beginning 2012 and a number of peer-reviewed research (102) on TeachLivE. All publications evidenced improved PSTs skills and learning, but there were rare and limited discussions into how to best use TeachLivE program in terms of a technical tool and the limitations of the program on specific skill acquisition. Although, this research focuses on teacher education, it provides many possible ideas for other researchers and simulation developers.

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## Supplemental Material

Supplemental material for this article is available online.

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