2021

Developing Instructional Technology Standards for Educators: A Design-Based Research Study

Helen Crompton
Old Dominion University, crompton@odu.edu

Carolyn Sykora

Original Publication Citation
Crompton, H., & Sykora, C. (2021). Developing instructional technology standards for educators: A design-based research study. *Computers and Education Open*, 2, 1-11, Article 100044. https://doi.org/10.1016/j.caeo.2021.100044

Computers and Education Open 2 (2021) 100044

Contents lists available at ScienceDirect

Computers and Education Open

journal homepage: www.sciencedirect.com/journal/computers-and-education-open

Developing instructional technology standards for educators: A design-based research study

Helen Crompton [a,*], Carolyn Sykora [b]

[a] Department of Teaching and Learning, Old Dominion University, 145 Education Building, Norfolk, VA 23529, USA
[b] Senior Director of ISTE Standards Programs, International Society for Technology in Education, 621 SW Morrison Street, Suite 800, Portland, OR 97205

ARTICLE INFO

Keywords:
Educational technology
Standards
Technology integration
Pedagogy
Teacher training
Teaching

ABSTRACT

Digital technologies are key tools that can be used to extend and enhance teaching and learning. However, empirical evidence show educators are unclear how to integrate technology and it is often used to support past teaching practices. Designbased research (DBR) involving a grounded theory design was used to construct a set of seven detailed education technology standards to provide guidance on how technology should be integrated and a set of 24 examples as indicators of these standards. This DBR mixed methods approach involved 2429 participants and gathered data from focus groups, surveys, and interviews. The DBR involved two macro cycles of design, implementation, analysis, and revision within the development of the standards. These standards are unique as they are the first empirically developed instructional technology standards for educators.

1. Introduction

Digital technologies are key tools that can be used to extend and enhance pedagogies leading to an increase in student motivation [50], interest [9], study skills [14], and student achievement [59]. Educators play a key role in the adoption of technology in K-12 education [29,41] and are expected to develop innovative ways to use technology to support student learning [32,35]. However, K-12 educators are only beginning to integrate technology in classrooms [54], and when technology is used, it often follows traditional teaching approaches [37,56]. Academics posit that concrete descriptions and measures for K-12 technology integration competencies [34,57], and a clear comprehensive set of standards are needed [15].

Having a general understanding is not sufficient for understanding technology use in the K-12 context. Past studies show that educators who were competent in using technology for personal and social needs, often did not have the ability to transfer and adapt them for classroom use [34,43]. Clear documentation of educator technology knowledge and skills are is needed [15] so that all educators are prepared to use technology effectively. Educational technology standards are a set of competencies that enable teachers to effectively integrate technology into the educational setting [42]. In this study, the standards are a level of attainment, and competencies are the knowledge and skills listed in those standards. A clear set of standards would provide a framework to support the development of knowledge and skills needed to leverage technology for educational purposes [44,52].

The purpose of this study is to answer this call in the academic literature by developing a set of standards for educators which will specifically explain the competencies needed for successful integration of technology into K-12 curriculum. These standards will provide clear documentation of competencies including a set of descriptors that explain what each standard would look like when implemented.

2. Literature review

The study of the focused use of digital technology in classrooms can be traced to the late 1940's [3]. Since their early inception, the use of digital technologies in schools has escalated exponentially to coincide with the advances in technologies. However, empirical findings indicate that pre-service teachers are not well prepared to use technology during their programs [6], and existing educators lack knowledge and skills to integrate technologies into the curriculum [54]. Furthermore, scholars (viz., [55] found that educators who do integrate technologies often use technologies with past teaching practices that add little to no change to teaching and learning.

Please note that during this paper the term *technology* refers to digital technologies that are electronic devices, systems, and resources. Instructional technology, also known as instructional design and

* Corresponding author.
E-mail addresses: crompton@odu.edu (H. Crompton), csykora@iste.org (C. Sykora).

https://doi.org/10.1016/j.caeo.2021.100044
Received 26 January 2021; Received in revised form 8 July 2021; Accepted 9 August 2021
Available online 11 August 2021

technology [26], is the development of instructional materials and integration of technologies within that instruction [39]. The term *educator* is also used in this study to include all educators that work in K-12 schools, such as reading, art, and gifted education specialists, as well as classroom teachers. The term *teacher* is also used to align to language used by organizations and existing terminology, such as pre-service teacher.

2.1. Educator competencies

Within instructional technology, effective technology integration has been the central debate since the emergence of technology in schools. This has led to the need for educators to gain skills and knowledge required for effective technology integration [3]. Educators do not need to be experts in technology but should leverage relevant technologies to engage students in learning [22]. Empirical findings show that educators who have technological skills and knowledge will integrate technology more effectively in the classroom [49]. Educator skills in the use of technology are important to provide a mode for transformative pedagogies that take advantage of the technological affordances to improve student learning [5,38]. However, it is important to specifically identify what those skills and knowledge are for educators to use technology more effectively in the classroom.

Governments and organizations advocate for K-12 technology preparation (e.g., [58]; The Council for the Accreditation of Educator Preparation -CAEP; the Interstate Teacher Assessment and Support Consortium -InTASC). The U.S. Department of Education, Office of Technology states that “Teachers need to leave their teacher preparation programs with a solid understanding of how to use technology to support learning” (p.35). CAEP and InTASC are the organizations that teacher preparation programs align their program standards for teacher accreditation, and both these organizations state that teacher candidates should be able to integrate technology across the curriculum.

Despite these efforts, empirical evidence shows that educators do not enter the classroom ready to integrate in technology, including those who consider themselves to be technology literate [3,15]. Specific guidance for technology integration would provide guidance to pre-service teachers gaining the skills to enter into the classroom, and for in service educators who may have been in the classroom for many years [17].

2.2. Technology integration frameworks

To support educators in effectively integrating technology into K-12 experiences, various frameworks have been developed. Before the examination of these frameworks, for transparency, we acknowledge that the definitions of technology integration are varied and also are used interchangeably with other terms, such as digital competence, digital integration literacy. On review, these are all terms to describe how technologies are used with students to perform various tasks. Ferrari captures the multifaceted approach to technology, and this is the definition that is used when technology integration is described in this study:

Digital competence is the set of knowledge, skills, attitudes, abilities, strategies, and awareness that are required when using ICT [Information Communication Technologies] and digital media to perform tasks; solve problems; communicate; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning, and socializing. ([16], p. 30)

This complex, multifaceted definition appears far removed from the gestalt-like K-12 technology integration frameworks available to educators, such as the Technological, Pedagogical, and Content Knowledge framework (TPACK: [36]), the Replacement, Amplification, and Transformation (RAT: [27]), and the Substitution, Augmentation, Modification, and Redefinition framework ([46]: SAMR).

TPACK is a framework presented as a three circle Venn diagram with each circle representing the three types of knowledge educators should have: technological, pedagogical, and content knowledge, which work in unison for effective integration. TPACK was developed based on theoretical knowledge from scholars [36]. This framework can have educators thinking about the intersections between the three main components of education. However, scholars critique the use of TPACK for educators. Angeli and Valanides [1] found that the framework has unclear boundaries. [7] purport that there are uneven intersections between the areas of TPACK which could connote some parts of the framework more important than others, and that it is unclear exactly what constitutes each section.

The RAT framework [27] has three levels that characterize different levels of integration. Replacement is when technology serves as a digital means to earlier, non-technology, instructional practices. Amplification is when technology increases efficiency, effectiveness, and productivity of non-technological instructional practices. Transformation is when technology invents new instruction, learning, and curriculum. Further investigation by Hughes and colleagues revealed that educators found the movement from amplification to transformation too great a leap and that modifications needed to be made to the framework [28].

Puentedura then adapted the RAT framework to create the postulated SAMR (2009) framework he presented to the educational community in a blog post. The SAMR framework has four levels of technology integration as a continuum. At the Substitution level, technology is being used to perform a task that can be accomplished without technology. Augmentation provides some additional benefit to the learning. Modification described when technology allows for significant task redesign. At the top of the framework, Redefinition is when technology is being used for learning in a way that could not happen without technology.

Again, scholars (viz., [2,8,23], have provided numerous critiques of the SAMR framework with the lack of theoretical explanation of the levels the absence of context in making technology usage decisions, problems with the rigid hierarchical structure, and the emphasis of the framework on product over process.. Both the critiques of the TPACK and SAMR frameworks highlight the lack of clarity and academics posit that concrete descriptions and a comprehensive set of standards are needed [15,34,57].

2.3. Extant educational technology standards for educators

The use of educational technology standards in K-12 have been identified as the driving force in improving an educators’ ability in extending and enhancing pedagogies, management skills (such as communication, time management), assessment, technology skills, instructional design, educator dispositions [47] record keeping and feedback [33]. With the call for a set of standards as guidance to educators and the identified benefits many subject-matter specific organizations have developed standards that include references to how technology should be used, such as; International Literacy Association, National Council of Teachers of Mathematics, National Council for the Social Studies, National Council for the Teachers of English, Council for Exceptional Children, Teaching English to Speakers of Other Languages, and International Literacy Association. These are useful providing direction from the subject-matter areas as to the importance of including digital technologies as tools for teaching and learning. However, they do not give specific instructions as to how to integrate these technologies.

There is technology guidance across subject-matter content. The U.S. National Education Technology Plan provides principles and examples to support the effective use of technology (Title IV A of Every Students Succeeds Act (2015) but does not provide a specific set of standards for educators to follow. In TASC (2020) has a set of model core teaching standards and learning progressions for teachers which offer guidance for ongoing professional development. The document states that technology is woven throughout the standards, but again, there are no specific standards on technology use for teaching and learning. ISTE (2008) does have a set of standards with five overarching standards with a total of 20 examples of each of those standards.

While the ISTE (2008) standards appear to be a comprehensive set for educators to use, these standards need to be updated on a regular basis to reflect technological and pedagogical developments as they can quickly become irrelevant and obsolete [24,40]. The ISTE standards are developed through input from various educational stakeholders, such as feedback gathered from groups [30]. however, there was not a formal empirical process used to collect and analysis the data. UNESCO (2018) have a more current set of standards with the UNESCO ICT Competency Framework for Teachers. These standards have six overarching parts that are unpacked in detail. Working with technology organizations (CISCO, Intel, ISTE, and Microsoft, UNESCO gathered a group of subject matter experts to examine past literature to determine what should be included in the standards. Similar to the ISTE standards (2008), the UNESCO standards (2018) are built from examining extant research, but they are not built through primary research.

Various types of research are valuable, for example, teachers may implement and evaluate new strategies, experts can come together to discuss research and practice. However, empirical methods provide a level of scholarly inquiry that provide a level of confidence in the rigor of the findings through a systematic, transparent method [11]. Scholars lament that standards are often developed without documented methods that call into question the validity and reliability of the frameworks or standards (viz., [8,21,23]). Standards provide a vision for the use of education technology in K-12 and those standards should be developed through empirical methods [51].

In reviewing all the extant standards described in this study, and from a meticulous review of the literature within peer review journals, it appears that there are no educational technology standards for educators developed through research. While there is ambiguity in the field around operationalization of integration models and existing frameworks are not empirically derived, there could be a risk that teachers are unclear of how technology should be integrated [15,57] and for the standards that are available, how robust, and accurate they are when they are based on the opinions of just a small group of people [12].

2.4. Purpose of this study

This study will address the gap in scholarly knowledge regarding the lack of empirically constructed educational technology standards (e.g., [51]) by developing a unique set of empirically constructed educational technology standards for educators. These standards will provide competencies to enable educators to successfully integrate technology into K-12 curriculum. These standards will be up to date, with relevance to current pedagogies and technologies. Furthermore, each standard will be accompanied by a set of descriptors that explain what each would look like enacted.

The research questions guiding this study are:

1- What standards should educators embody when integrating technology into K-12 teaching and learning?
2- What would be indicators of educators meeting these standards?

3. Method

3.1. Participants

A total of 2429 participants were involved in this large study representing 38 countries and 48 US States. To organize the participants and their role in this study, Table 1 presents the participant role, number, a description of how they were selected, and their role in the study. For example, expert leaders feedback group were chosen from education technology leadership positions and asked to provide input in this capacity. The Technical Focus Group, Stakeholder Advisory Group, and Expert Focus Groups, were a purposeful sample in reaching out to known experts to provide feedback on specific aspects of the standards. For the Expert Leader Feedback Group, again, leaders in the field of educational technology were asked to participate providing input from a leadership perspective. The Public Focus Group, Public Survey, and Twitter group participants were all invited to volunteer to be part of this study through educational technology special interest groups and were a mix of K-12 stakeholders.

Table 1
Study participants.

Participant Title	N=	Role/Participant Description
Technical Focus Group	12	K-12 representative voices (state leaders to classroom educators). This group provided feedback on the language to articulate the standards.
Stakeholder Advisory Focus Group	14	K-12 representative voices (association leaders to classroom educators). This group provided feedback on the standards as a whole and strategic questions to develop the standards further.
Expert Focus Groups	8	This group of educational technology experts (selected from leadership positions in educational technology organizations) provided feedback on the standards using data gathered and language used in the standards.
Expert Leader Feedback Group	21	This group of educational technology experts (these were selected from higher ranking leadership positions, such as COA, CAO of large educational technology organizations) provided feedback on the standards after each research cycle to comment on the standards as a whole. This was a group of leaders from the International Society for Technology in Education.
Public Focus Group	1,735	Participants with roles connected to K-12 educational technology provided feedback as a group at conferences, symposiums, and other educational technology events attended by members of professional international educational technology organizations. Public participants for the focus group *and public survey* were from 48 US States 87% and then 37 Other countries: Algeria, Afghanistan, Argentina, Australia, Azerbaijan, Bahrain, Canada, China, Colombia, Cyprus, Denmark, Ecuador, Egypt, Germany, Ghana, India, Italy, Lebanon, Malaysia, Mexico, Philippines, Poland, Portugal, Puerto Rico, Qatar, Russia, Saudi Arabia, Singapore, Sweden, Switzerland, Thailand, Trinidad/Tobago, Turkey, UAE, UK, Ukraine, US Virgin Islands.
Public Survey	534	Participants with roles connected to K-12 educational technology provided individual feedback via an electronic survey. These were contacted as members of international educational technology organizations.
Twitter Group	100	Participants with roles connected to K-12 educational technology took part in five separate Twitter chats. Note, this number only accounts for active Twitter users in the conversation.
Interviewees	5	One representative from the National Board for Professional Teaching Standards, National Association of Secondary School Principals, Christensen Institute, Partnership for 21st Century Skills, and the National Education Association provided perceptions on the standards based on requirements from the corresponding organizations.
Total	2,429	

Note: Participants involved at conferences (e.g., Public Focus Groups) were agreeing to take part in highly active focus group discussions, see data section on Public Focus Groups.

The “Technical Focus Group”, “Stakeholder Advisory Focus Group”, “Expert Focus Groups”, “Expert Leader Feedback Group”, and the

Interviewees remained the same for Macro Cycle One and Two. At the end of Macro Cycle One a new call was put out for participants in the “Public Focus Group”, “Public Survey Participants”, and “Twitter Group Participants” therefore participants in these groups changed across the macro cycles. These numbers for each macro cycle are reported in the corresponding sections of the research protocol.

3.2. Design-based research protocol for this study

The design-based research protocol selected for this study was developed by Gravemeijer and colleagues [18,19,20]. This protocol was designed to connect directly with K-12 educators and has been used in previous K-12 educational technology empirical work (e.g., [45,48,60]). The purpose of design-based research is twofold; 1) the development of a theory, and 2) the creation of an educational artifact, such as a curriculum, computer program, or set of standards, as an embodiment of that theory.

The central element of the productive design-based theorizing is the development of an *ontological innovation*, which is theory doing real design work in generating, selecting, and validating design alternatives that are consequential to learning [13]. The ontological innovation is also described as the local instructional theory, local in that it is only applicable for a specific context, in this case educational technology and instructional in that it is a part of the instructional design. For example, standards are directly used to develop instruction from the pedagogy selected to the part the technology will play within that instructional design. The ontological innovation in this study is a set of educational technology standards that are developed through macro cycles involving a process of design, implementation, analysis, and revision.

This design-based research study involved two macro cycles, one of the two macro cycles for this study is presented in Fig. 1. Note the occurrence of the three phases within the macro cycle: (a) instructional design, (b) experiment and mini cycle analysis, and (c) retrospective analysis. In the design phase, a set of standards are developed as a conjectured theory of ontological innovation. The experiment is when the standards are tested to see if they work for the purpose they are designed. There is also a mini cycle of analysis, as data are examined throughout the experiment and revisions are made as needed throughout the process. The retrospective analysis is when all data are analysis from the entire macro cycle. This then repeats into the next macro cycle. The full protocol of each of these phases of design-based research are explained below.

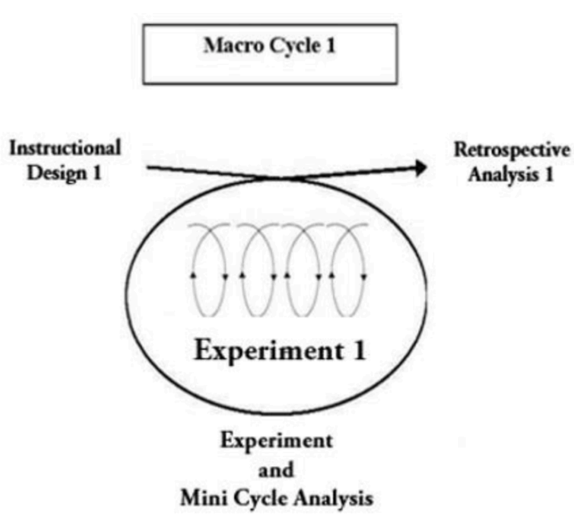

Fig. 1. One macro cycle of design-based research [20].

3.3. Instructional design

The first macro cycle of instructional design involved a literature review. Following the design-based research method, the literature review served as part of the research in the development of a conjectured theory of ontological innovation in addition to highlighting the gaps in the research. The initial conjectured ontological innovation is a set of standards to be used as a starting point which are then iteratively edited, revised, and rewritten to then develop into the final set of educational technology standards. From the review of the literature it appeared that there were no existing empirically developed standards to choose from. The ISTE standards for teachers [30] were identified as theconjectured set of educational technology standards as they provided the most comprehensive list of standards from the literature review. This provided a base for participants to consider and critique. These also provided the initial conjectured local theory as part of Gravemeijer, and van Eerde, [20] DBR method.

These standards were examined by experts in technical (n=12), stakeholder (n=14), expert (n=8), public (n=484) focus groups; expert leader feedback (n=21); Twitter group (n=20), and public survey (n=50). Following the coding of the focus group data, a set of standards was developed as a conjectured theory of ontological innovation of how educators should incorporate digital technologies into K-12 education. In the instructional design of the second macro cycle, a revised set of standards was developed from the findings of macro cycle one, a further review of the literature and the revisions were examined by a set of expert leaders to provide feedback and further revisions.

3.4. Experiment and mini cycle analysis

In Macro Cycle One, the standards were open to use for two months by those in K-12, and feedback was gathered from public surveys (n=288), public focus groups (n=369), and Twitter discussion groups (n=60), technical focus group (n=12), stakeholder advisory group (n=14), and interviews (n=3). The use of the standards involved participants taking the current conjectured standards and they were tasked with reading the standards carefully, testing the standards based on if they were adopted for use in the school or district to be used in instructional activities. This included, continually critiquing the standard based on actions educators take, the language of the standards, and the concrete examples. Depending on the role of the participant, they provided slightly different feedback, for example, the education technology experts used the standards in working in leadership roles with educators and provided feedback based on those roles.

In Macro Cycle Two, the standards were used for two months by those in K-12 and feedback was gathered from public surveys (n=102), public focus groups (n=882), and Twitter discussion groups (n=20), technical focus group (n=12), stakeholder advisory group (n=14), and interviews (n=2). During the experiment, any changes needed to be rectified immediately were done so through the mini cycle of analysis.

The mini cycle analysis within the experiment in DBR describes the multiple times data and that immediate actions can be taken. For example, during an interview, if a spelling mistake was found in the standards, this would be immediately corrected and all the following examination by the different groups would be using the revised version. However, the reporting of the changes is listed in the retrospective analysis section when all the findings are presented from that macro cycle.

3.5. Retrospective analysis

During Macro Cycle One and Two, all data gathered from the design and experiment were analysis and the standards were revised in Macro Cycle One for Macro Cycle Two. All necessary changes were made using all the findings from the data. The revisions in Macro Cycle Two were used to develop the set of standards at the conclusion of the study.

3.6. Data collection and analysis

A distinct characteristic of design-based research is that multiple sources of data are iteratively collected to gain a rich understanding to inform the design and a comprehensive record of the process [10]. Data in this study includes data from focus groups, surveys, observations, interviews, expert feedback. A diagrammatical representation of the study and data collection points is presented in Fig. 2.

3.6.1. Focus groups and surveys

Focus group participants worked in groups of 6–10 people were presented with the standards which they then discussed in groups of approximately 8–10 people. To test the standards, questions were asked to gain the participants opinions on the language and content of each of the standards and how they can be improved. Questions had them thinking about how they would be put into practice and mimicking what they would look like in an educational setting. Either having the participant thinking about how they would implement these standards or having other teachers implement the standards depending on their role in the school or district. These questions were discussed as a group. Final input from the groups were added via the online survey by the table leader. This included additional thoughts and comments from the group. As concomitant data collection, researchers also collected observational notes from the focus groups (see the observation section for further details on the observations). Other participants completed the survey independently. To test the standards, they were given time to explore and test out the standards in their classrooms or with other teachers depending again on their role in the school or district. They then provided feedback via the online survey.

The online survey for the Public Focus Groups and Public Survey consisted of 38 questions. The standard was given, and the participants were asked to respond via a four-point Likert scale rating the standard from strong to weak based on the standard description, fit to educational technology best practices, skills and knowledge from the participants, and language. This was immediately followed by an open text response to recommendations for changes. For the Public Survey, other questions gathered information on job title and state or country of the participant. Participants were provided with a link and the online program guided them through each question with the option of being able to go back to past questions if the participant wished to do so. Data from the instructional design in Macro Cycle One and experiment in Macro Cycle One and Two; (1) expert focus groups, (2) technical focus group, (3) stakeholder advisory group, (4) public focus groups, (5) public survey, and (6) Twitter discussion group were quantitatively gathered from Likert ratings and the text responses were qualitatively coded.

3.6.2. Observations

During the Public Focus Groups, observations were conducted during the focus groups to gather further data to support in triangulating the findings. The observation protocol had the researchers listening to a group discussing the questions asked to test the standards. Observers focused on transcribing the major discussion points and attitudes towards the rationale or defense for what aspects of the standards language was being kept or removed. The survey input of final comments were also gathered, but this data captured the reasoning behind why the group make those decisions.

Data from the observations were coded.

3.6.3. Interviews

During the experiment in Macro Cycle One and Two, to test the standards, interview participants responded to 12 semi-structured questions. Three questions asked interviewees about the general state of technology in education. This enabled the researchers to capture information that the participant wanted to share about educational technology that the researchers may not have considered. Then a following nine questions focused on specific topics, such as key digital considerations and skills, the role of standards, and the positioning of standards within the interviewee's country. These questions were chosen to allow the interviewee provide feedback on the content that needed to be included in the final standards, as well as provide contextual information on the views about the purpose of standards that will support the development of both the content and the language used to craft the standards. The semi structured interview format aligned with the grounded coding design (Chezan, 2012) that was then used to code the interview transcripts.

3.6.4. Expert feedback

During the retrospective analysis of Macro Cycle One and Two,

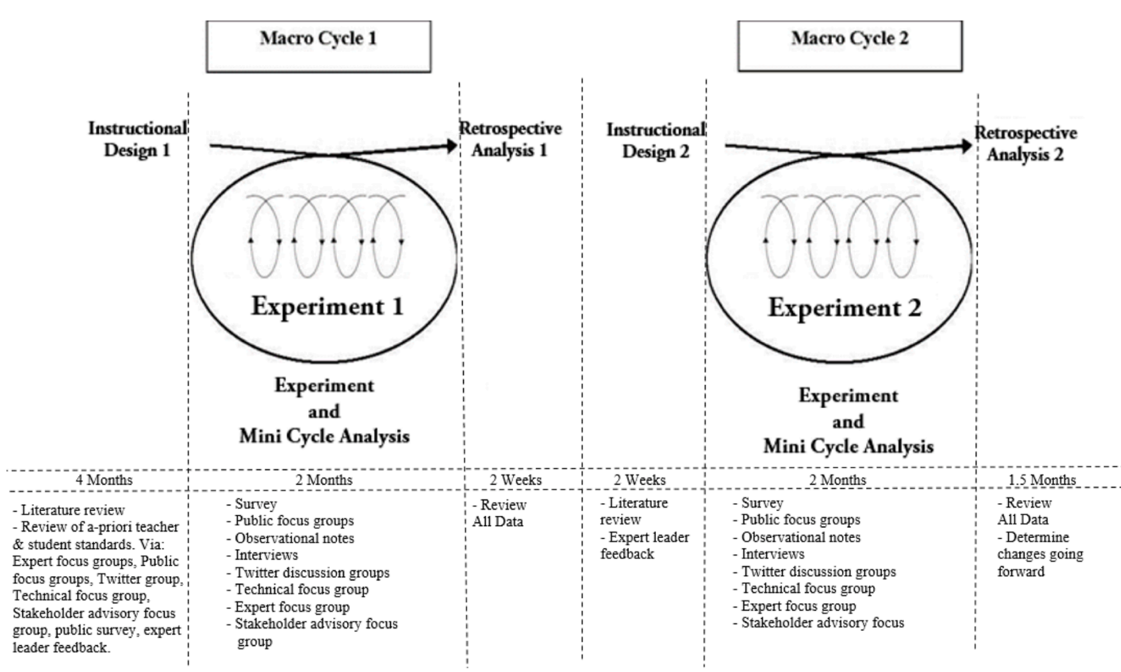

Fig. 2. A diagrammatical representation of the study and data collection points.

experts were presented with the complete set of revised standards to provide open general feedback. These data were then triangulated with the additional data sources and used to further refine the standards.

3.6.5. Coding

Data from the surveys, focus groups, observations, interviews, and expert feedback were qualitatively coded using a grounded theory design with a constant comparative method [53]. In the first step, the participant responses were open coded to identify important themes in the data and they were labelled. *In vivo* codes were also selected as the participants' verbatim terms offered appropriate descriptive coding terms [25]. The study of the data was an iterative and inductive process. The initial codes led to intermediate coding and the constant comparison of feedback data to feedback data, feedback data to codes, codes to codes, codes to categories, and categories to categories. The codes were deemed to be theoretically saturated once data continued to fit into existing categories and no additional categories were needed. Inter-rater reliability was calculated using percentage agreement [4]. Coding was conducted by two researchers independently, who came together to discuss and edit the codes to reach a 96% agreement after reviewing all the data. After the final discussion this reached a 99% agreement. In this study, the findings of what should be in the standards and indicators, and the revisions that need to be made to the standards are what resulted in the conjectured theory of ontological innovation.

4. Findings and discussion

The purpose of this study was to determine what standards educators should emulate when integrating technology into K-12 teaching and learning, and what indicators would identify the types of activities educators would be doing to meet these standards. With the design-based research method, findings were produced throughout the process. From the findings at the conclusion of the initial instructional design, a set of standards were selected as a conjectured theory of ontological innovation of how educators should incorporate digital technologies into K-12 education [30]. The findings of the retrospective analysis of Macro Cycle One and Two are presented in the next section. In the retrospective analysis, the researcher examines the entire collection of data from the macro cycle describing findings and changes that were made to provide the conjectured set of standards.

Retrospective analysis: macro cycle one

From examining the data, it was interesting to note that while there were a variety of participants from classroom teachers to school leaders and organizations, there appeared to be a unified voice in the themes of what they believe should be addressed in the standards. Participants responded through a variety of lenses, with classroom educators describing the standards from the classroom perspective in supporting students, and school leaders focusing on using the standards for pivoting a school system. While the participants data across all participnts matched towards the content of the standards, school leaders expressed concern in gaining support from the educators if they were to adopt the standards, and educators showed concern that those in school leadership roles may not welcome the emphasis on teacher empowerment.

Through the grounded coding, a set of codes were developed and substantiated with the quantitative Likert scores See Fig. 3. These codes are *in vivo* (using terms described by participants) and highlight the themes emerging from the data. Two overarching themes developed: (1) empowered educator and (2) learning catalyst, which then led to a set of seven axial codes. These seven codes show a trend as they identify characteristics educators would embody using best practices in technology integration.

The initial two overarching codes, empowered professional and learning catalyst, highlight the desire from participants that through the standards, educators are empowered to act with confidence, authority, skills, and knowledge to reach a goal and look for next steps. *"Empowerment is a main piece, knowing your scope of control/influence and how can you empower yourself to do these things"* (Technical focus group participant), *"Standards should not be considered something that is done to teachers, but of where they want to be"* (stakeholder advisory focus group). This is very different from UNESCO's (2018) ICT Competency Framework for Teachers as the focus of that framework is promoted as a tool to be used for assessing teachers. Empowerment also connected to students, *"I would actually advocate for something calling out the key role teachers play in creating empowering environments and scaffolding students as they learn how to be empowered"* (Technical Focus Group). Empowered professional led to the three sub codes of learner, leader, citizen.

Learning catalyst is the educator creating learning experiences that act as a stimulant, motivator, and incentive for learning. *"As a learning catalyst, teachers are attending to the students with personalization and improving learning outcomes"* (Interviewee). As a member of the stakeholder advisory focus group said, *"How are we enabling the students [technology integration] standards to happen - what do all of our educators at*

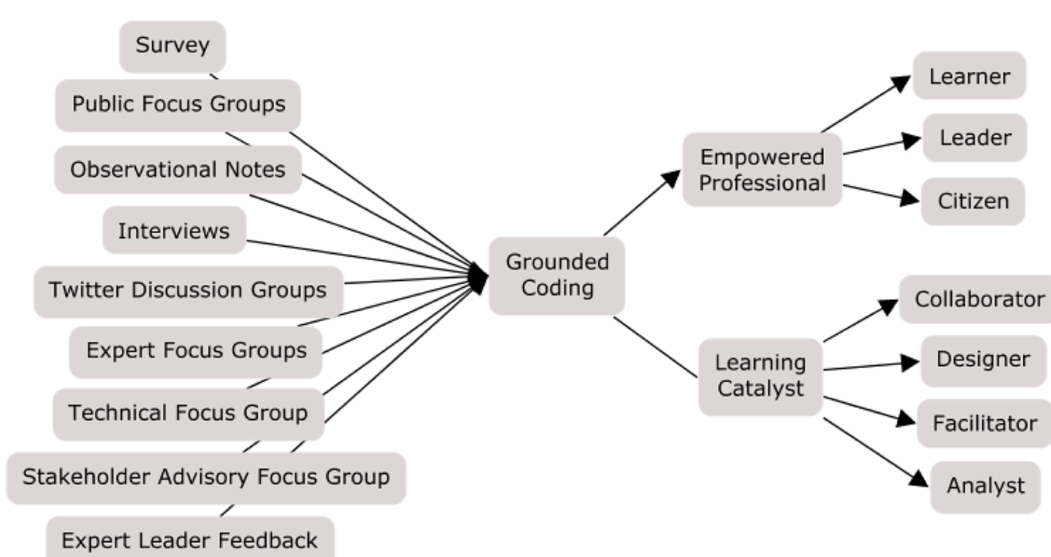

Fig. 3. Final codes from macro cycle one.

different levels need to make these conditions happen" (Stakeholder advisory focus group). This was extended and reiterated by a member of the expert focus group who stated:

A learning catalyst provides an alternative to technology integration. Technology integration can be embedding a tool in an activity, but this doesn't convey the breadth or scope of the role of the educator as a learning catalyst. Through meaningful and purposeful use of technology, educators can be learning catalysts, who deepen content learning through instructional strategies, alternative assessments, accessibility, engagement. (Expert Focus Group)

The term, learning catalyst, describes how educators promote learning with technology as collaborators, designers, facilitators, and analysts. These are the final four axial codes. Data coded for empowered professional and learning catalyst often included comments about students and empowering students to meet their learning goals by using technology and educators as a catalyst for making that happen. The ISTE Standards for Students [31] emerged from the data as an up-to-date set of standards for students and are used in this study when describing what competencies students should emulate in learning with technology.

The seven axial codes replace the much longer titles of each standards found in the initial conjectured theory. This met the request by participants for "simplicity" and "accessible" language. It also addressed the request for "empowering language" as these codes have active language of the educator accomplishing these standards as they are designers, leaders, analysts etc.

The revised names for the standards are listed in Table 2 with a description of the standard, and examples of participant data that led to those changes to the conjectured standards.

Retrospective analysis: macro cycle two

Data in Macro Cycle One led to major revisions to the initial conjectured standards of how educators should integrate technology into K-12 teaching and learning. Scholars and organizations (viz., [24,40]) called for a comprehensive set of standards for educators to use that are relevant and up to date. Scholars (viz., [12,51]) also highlighted a need for standards that were not just build on the opinions of a few experts but developed through empirical means using a rigorous process gathering a variety of data. In this final phase of Macro Cycle Two, that call for relevant, up-to-date, empirically developed standards was addressed.

This final macro cycle brought about the concluding changes, to further refine the language in the standards. Five of the seven standards were rephrased to respond to the call that the standards to be clear, avoid jargon, and include all the necessary components needed to explain what the standards entail. In the earlier review of the literature, scholars, such as Ferrari [16], provided a list of digital competences, describing the skills, attitudes, abilities, strategies, and awareness required when using digital tools.

Examples of these changes include:

- Learner standard - The inclusion of the language "local and global" when describing professional learning communities.
- Leader standard - The inclusion of community in leader engagement as well as the school and district.
- Citizen – Specific language to explain the citizenship components included as safe, ethical, and legal behaviors.
- Collaborator – Inclusion of language focused on time and educators dedicating time to collaborate.
- Designer – Language changes from *supporting* students to *empowering* students and standard indicators were made more concise.
- Facilitator – Standard indicators were shortened from seven to a more concise five while still covering the important concepts.
- Analyst – Standard indicators were presented in a concise format while still covering the important concepts.

Table 2
Revisions to the conjectured standards and data examples.

Standard Name	Standard Description	Participant Data Examples
Empowered Educator		
Learner	Teachers are professionals who are committed to improving their practice through professional learning, monitoring research and proven approaches, and learning from and with others.	*"Intentionality of progression to get to this point and next step"* (TFG). *"Constantly seek out PL opportunities"* (PS). *"What teachers have to learn about their own learning"* (Int.). *"Educators should focus on professional learning and professional growth"* (SAG).
Leader	Teachers are professionals who transform learning with technology through their contributions to a shared vision, advocacy, and expertise.	*"Identifies needs in his or her community and actively seeks to fulfill them"* (TFG). *"Advocate (equity)", "Change agent", "Vision/ visionary"* (TFG). *"Influencing outside of your PLN; intentional choosing resources and professional learner opportunities that challenge or learn a different perspective"* (TFG)
Citizen	Teachers are professionals who exercise and model the digital rights, responsibilities, and opportunities of living in an inter-connected, digital world.	*"Model and teach safe and ethical use of digital information"* (PFG). *"Teacher models positive digital citizenship"* (PS). *"Bolster students' educational goals by engaging with families to reduce barriers to digital access and actively communicate with them in ways that are culturally relevant"* (TFG).
Learning Catalyst		
Collaborator	Teachers prioritize collaboration to improve practice by learning and sharing resources, ideas and problem solve.	*"Teachers need to be effective communicators, find wider audiences for their students' work"* (PFG). *"Teacher + student collaboration"* (PS). *"Communication - family, community (equity, including language); parent as collaborator"* (EFG).
Designer	Teachers build a robust toolkit of skills to design learning activities and environments that support students achieving student technology standards.	*"Design thinking - empathy, iteration, test theories, innovate"* (TFG). "*We should focus back on effectively designing learning across a variety of online environments. I think that it is a specific and important skill to be able to be a good instructional designer in LMS and other online/virtual environments"* (TFG)
Facilitator	Teachers evolve their role to become a facilitator of learning who empowers student and apply student technology standards in their practice.	"I like to say educators are facilitator and they drive towards personalized learning; wonder why we don't call it out" (PFG). *"What's missing in that section is students. Expand on the mindset of leading with students (although avoid managing, controlling). Weave that in."* (PFG).
Analyst	Teachers understand and use data to inform their	*"Teachers need to know how to support shifts with*

(*continued on next page*)

Table 2 (*continued*)

	instruction and support students to achieve their learning goals.	*concrete evidence"* (PFG). Analyst is a good term for what educators do; some votes for "Evaluator (Ob).
Note: Int. = Interviewee, TFG = Technical Focus Group, PFG = Public Focus Group, PS = Public Survey, EFG = Expert focus group, Ob = Observation		

At the end of the retrospective analysis in Macro Cycle One, the findings were used to develop a revised set of conjectured standards that included changes to the standard titles and descriptions as well as indicators of what these standards would look like in action (See Appendix A).

Note that these are examples and not an exhaustive list of changes. These can be seen when comparing the second set of conjectured standards in Appendix A and the final standards presented in the next section.

One of the new additions to the standards from the initial conjectured standards was the inclusion of references to the learning sciences. In Macro Cycle Two, this was made even clearer with changes to the language as it now states that educators "*stay current with research that supports improved student learning outcomes, including findings from the learning sciences*". The learning sciences examine how learning takes place through cognitive-psychological, social-psychological, cultural-psychological, and critical theoretical foundations. This is typically found in scholarly academic journals, but data from this code focus on educators using research from accessible formats, such as teacher magazines. Educators can learn, what pedagogies, tools, strategies, and activities appear to work best for learners. Technology is a tool that can be used to gather, curate, and utilize that information. As described from a member of the expert focus group:

Learning Science is still a foggy concept in the field. Somehow, we need to get to the point that teachers should stay current with brain and learning science with a critical eye toward implementing research-based best practices or discontinuing practices that have been shown to no longer apply (ex: myths like left brain/right brain). (Expert Focus Group).

This was echoed by those in the public focus group and through the observation notes – "*Teachers need to be up to date with learning sciences. Be more creative in their design. Need to understand the learning science behind the technologies they are using*".

The learning science was often highlighted in participant responses. The standards of UNESCO's (2018) ICT Competency Framework also highlight as one of their six foci in describing the need for ongoing professional development through a variety of sources that use the learning sciences, such as webinars, courses, and literature.

From the data examined during the retrospective analysis in Macro Cycle Two, changes were made to the conjectured standards to provide the final empirically constructed theory of ontological innovation as to how educators should integrate technology into K-12. These standards are presented in Table 3.

5. Limitations and future research

With the rapid progression of technologies and the continuous empirical work that informs the learning sciences, researchers recognize that these standards will need revising in the future. This will ensure the standards are current and relevant. Future researchers can use these standards as a priori and utilize a similar design-based research methodology, rigorously described in this study, to develop a new set of standards when the activities, language, and goals become dated. It is also recognized that while these are a comprehensive set of standards, they are only for those focused on the use of technology across K-12

Table 3
Theory of ontological innovation: technology integration standards for K-12 educators.

Standard	Indicator
1. Learner Educators continually improve their practice by learning from and with others and exploring proven and promising practices that leverage technology to improve student learning.	a. Set professional learning goals to explore and apply pedagogical approaches made possible by technology and reflect on their effectiveness. b. Pursue professional interests by creating and actively participating in local and global learning networks. c. Stay current with research that supports improved student learning outcomes, including findings from the learning sciences.
2. Leader Educators seek out opportunities for leadership to support student empowerment and success and to improve teaching and learning.	a. Shape, advance and accelerate a shared vision for empowered learning with technology by engaging with education stakeholders. b. Advocate for equitable access to educational technology, digital content and learning opportunities to meet the diverse needs of all students. c. Model for colleagues the identification, exploration, evaluation, curation and adoption of new digital resources and tools for learning.
3. Citizen Educators inspire students to positively contribute to and responsibly participate in the digital world.	a. Create experiences for learners to make positive, socially responsible contributions and exhibit empathetic behavior online that build relationships and community. b. Establish a learning culture that promotes curiosity and critical examination of online resources and fosters digital literacy and media fluency. c. Mentor students in the safe, legal, and ethical practices with digital tools and the protection of intellectual rights and property. d. Model and promote management of personal data and digital identity and protect student data privacy.
4. Collaborator Educators dedicate time to collaborate with both colleagues and students to improve practice, discover and share resources and ideas, and solve problems.	a. Dedicate planning time to collaborate with colleagues to create authentic learning experiences that leverage technology. b. Collaborate and co-learn with students to discover and use new digital resources and diagnose and troubleshoot technology issues. c. Use collaborative tools to expand students' authentic, real world learning experiences by engaging virtually with experts, teams, and students, locally and globally. d. Demonstrate cultural competency when communicating with students, parents and colleagues and interact with them as co-collaborators in student learning.
5. Designer Educators design authentic, learner-driven activities and environments that recognize and accommodate learner variability.	a. Use technology to create, adapt and personalize learning experiences that foster independent learning and accommodate learner differences and needs. b. Design authentic learning activities that align with content area standards and use digital tools and resources to maximize active, deep learning. c. Explore and apply instructional design principles to create innovative digital

(*continued on next page*)

Table 3 (*continued*)

	learning environments that engage and support learning.
6. Facilitator Educators facilitate learning with technology to support student achievement of the 2016 ISTE Standards for Students.	a. Foster a culture where students take ownership of their learning goals and outcomes in both independent and group settings. b. Manage the use of technology and student learning strategies in digital platforms, virtual environments, hands-on makerspaces or in the field. c. Create learning opportunities that challenge students to use a design process and computational thinking to innovate and solve problems. d. Model and nurture creativity and creative expression to communicate ideas, knowledge, or connections.
7. Analyst Educators understand and use data to drive their instruction and support students in achieving their learning goals.	a. Provide alternative ways for students to demonstrate competency and reflect on their learning using technology. b. Use technology to design and implement a variety of formative and summative assessments that accommodate learner needs, provide timely feedback to students, and inform instruction. c. Use assessment data to guide progress and communicate with students, parents, and education stakeholders to build student self-direction.

education. While these standards may be beneficial to those in higher education, future researchers may want to conduct a similar study that involves participants from the higher education sector. It is also important to note that with the large number of participants (2,429), it was not viable to determine if all these participants rigorously tested and/or explored the standards before completing the survey, and if the self-report input matched what they did actually find from using the standards.

From the development of these standards, future researchers could further examine how educators use these standards and how they can be included in professional development activities. While there were 2,429 participants involved in this large study, it may be more representative of the international community to have a larger number of participants from more countries providing their input. Future studies may focus efforts in gaining an in-depth understanding of specific differences in what instructional technology standards should encompass across countries.

6. Conclusion

Design-based research was used in this study involving 2429 participants from 38 countries to develop a unique empirically constructed theory of ontological innovation of how educators should integrate technology into K-12 instruction. This study followed the call for preparing educators [22] with up-to-date, relevant, education technology standards [12], developed through empirical methods [51]. Through a cyclical method of design, experiment, and retrospective analysis, the theory of ontological innovation was developed to provide a robust set of educational technology standards for K-12 educators. These include seven standards titled Learner, Leader, Citizen, Collaborator, Designer, Facilitator, and Analyst, accompanied with a standard description and a total of 24 indicators that provide examples of types of activities educators would do to meet these standards.

Participants used and provided feedback on the standards representing voices including K-12 educators, education technology experts, teaching association leaders, and educational leaders at all levels. Two overarching themes emerged: empowerment and learning catalyst. Empowerment is used throughout the standards for both educator and student empowerment through the use of technology. This connects with the first three standards - Learner, Leader, and Citizen, that have educators, and students improving their practice; seeking out leadership opportunities; and contributing responsibly to a digital world. Learning catalyst is the educator creating learning experiences that act as a stimulant, motivator, and incentive for learning. This connects with the final four standards – Collaborator, Designer, Facilitator, and Analyst. These have educators, and students dedicating time to collaborate; design authentic, learner-driven activities and environments; facilitate learning with technology; and use and understand data to drive instruction.

This study has provided an extensive contribution to the field of educational technology by providing the first set of empirically developed standards that delineate how educators should be using technology in K-12. Extant standards have shared the opinions of individual scholars and small groups of practitioners and experts. This work provides input from 2429 K-12 stakeholders from 38 countries. By involving a large number of participants from a variety of roles in education ensures a robust, relevant, comprehensive set of standards. This exceeds those extant standards that have typically resulted from gathering data from a literature review or asking the opinion of a small group of experts. The empirical methodology provides transparency and accountability in the research process.

One of the initial issues for developing a new set of standards was to support the educators in understanding how to use digital technologies to support their teaching practice. To ensure the standards provide clear direction, a set of concrete examples accompany each standard. Educators wanting to adopt these standards for use in their own practice are supported with these concrete examples that they can put directly into practice without any confusion that may be caused with grand overarching standards statements. As schools, or school districts adopt these standards, it would be prudent to give time for educators to review and plan for implementation. It would be important for educators to take a step-by-step approach to adoption and implementation of standards, perhaps setting a goal of working on one or two standards at a time to feel comfortable and successful, before taking on additional standards. These standards and examples can be used to support educators, students, school leaders, policy makers, funders, and also a springboard for future researchers to further empirically examine educational standards for educational leaders, and technology specialists.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Conjectured theory at the conclusion of macro cycle one

Standard	Indicator
1. Learners Teachers are professionals who are committed to improving their practice through professional learning, monitoring research and proven approaches, and learning from and with others.	a. Embrace continuous learning of how to transform learning with technology, set goals for professional growth and reflect on practice, and apply evolving pedagogical strategies that leverage technology. b. Keep abreast of emerging learning science research and collaborate with colleagues and experts to explore how to apply proven approaches with students and within the learning process and environments. c. Model with colleagues and students social learning through the use or creation of online personal and professional learning networks.
2. Leader Teachers are professionals who transform learning with technology through their contributions to a shared vision, advocacy, and expertise.	a. Engage as teacher-leaders in school or district-wide efforts to shape, advance and accelerate a shared vision of empowered learning with technology. b. Advocate for equitable access and reducing the digital opportunity gap with colleagues, administrators, parents, and the community. c. Engage as teacher-leaders to inform technology purchase and adoption decisions by identifying, evaluating, and curating digital tools, applications, and resources.
3. Citizen Teachers are professionals who exercise and model the digital rights, responsibilities, and opportunities of living in an inter-connected, digital world.	a. Exhibit for colleagues and students ethical and legal practice with digital tools and resources, and model positive, socially responsible behavior in interactions online. b. Model for students and empower them to manage personal data, protect privacy and manage digital identity. c. Understand the implications of data collection on student privacy and advocate for the awareness and protection of student and learning analytics data. d. Engage with families to bolster students' educational goals and reduce barriers to digital access, and proactively communicate with families in ways that exhibit cultural competency.
4. Collaborator Teachers prioritize collaboration to improve practice by learning and sharing resources, ideas and problem solve.	a. Establish dedicated time to collaborate with colleagues to plan and share ideas for using technology to create authentic learning experiences. b. Collaborate and co-learn with students to explore and experiment with digital tools and resources that support learning, and to diagnose and troubleshoot technology issues. c. Use collaborative tools to engage virtually with experts, teams, and students, locally and globally, to expand students' authentic, real-world learning experiences.
5. Designer Teachers build a robust toolkit of skills to design learning activities and environments that support students achieving the 2016 ISTE Standards for Students.	a. Redesign learning activities around pedagogies that leverage the available technology, digital environments, tools, and resources to maximize an authentic, active, learner-driven process that aligns with content area standards. b. Design learning experiences that use technology to accommodate learner variability, personalize learning, and engender student choice, self-direction, and goal setting. c. Keep current with effective instructional design practices for a variety of digital learning environments—including online, blended, mobile—and curate digital educational resources and tools to enhance student engagement and learning. d. Create a variety of learning environments that use effective teaching strategies and leverage digital tools and resources to manage and support the learning process.
6. Facilitator Teachers evolve their role to become a facilitator of learning who empowers students and apply the 2016 ISTE Standards for Students in their practice.	a. Adopt role as classroom facilitator to promote a culture of student agency where students establish their own learning goals, reflect on learning, and assume responsibility for learning outcomes. b. Implement strategies that address learner variability and provide opportunities for personalized learning, student choice and individualized pacing. c. Become adept in applying effective learning strategies and managing the learning process in a variety of classroom configurations and digital environments, including online and emerging virtual environments. d. Promote exemplary research skills to find and critically evaluate data and information and support students in curating resources for their intellectual pursuits. e. Model and support students in the use of digital tools or applications to deploy a deliberate design process for creating or innovating solutions. f. Engage students in formulating and solving problems that leverage computing power and rely on algorithmic thinking, representing data, and modeling to test solutions. g. Cultivate creative student expression in choosing and using digital tools, platforms, and resources to communicate or publish original works.
7. Analyst Teachers understand and use data to inform their instruction and support students to achieve their learning goals.	a. Design a variety of formative and summative assessments that capitalize on technology to provide immediate feedback to students, offer alternatives that empower students' choice in demonstrating their learning, and include competency-based approaches that allow personalized pacing. b. Access, analyze and use quantitative and qualitative data to effectively respond to student needs and instruction. c. Understand student assessment input and output and use that information to facilitate ongoing engagement with students and parents to help guide student progress.

References

[1] Angeli C, Valanides N. Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: advances in technological pedagogical content knowledge (TPCK). Comput Edu 2009;52(1):154–68.

[2] Crompton H, Burke D. Mobile learning and pedagogical opportunities: A configurative systematic review of PreK-12 research using the SAMR framework. Computers & Education 2020;156. 10.1016/j.compedu.2020.103945.

[3] Bakir N. Technology and teacher education: a brief glimpse of the research and practice that have shaped the field. TechTrends 2016;60:21–9.
[4] Belur J, Tompson L, Thornton A, Simon M. Interrater reliability in systematic review methodology: exploring variation in coder decision-making. Sociol Methods Res 2018;13(3):1–29. https://doi.org/10.1177/0049124118799372. https://doi-org.proxy.lib.odu.edu/.
[5] Blundell C, Lee KT, Nykvist S. Moving beyond enhancing pedagogies with digital technologies: frames of reference, habits of mind and transformative learning. J Res Technol Edu 2020;52(2):178–96. https://doi.org/10.1080/15391523.2020.1726235.
[6] Bowsher, A., Sparks, D. & Hoyer, K. M. (2018). Preparation and Support for Teachers in Public Schools: Reflections on the First Year of Teaching. Stats in Brief. NCES 2018-143. National Center for Education Statistics.
[7] Chai CS, Ling Koh JH, Tsai CC, Lee Wan Tan L. Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). Comput Edu 2011;57:1184–93.
[8] Cherner T, Mitchell C. Deconstructing edtech frameworks based on their creators, features, and usefulness. Learn Media Technol 2021;46(1):91–116. https://doi.org/10.1080/17439884.2020.1773852.
[9] Christensen R, Knezek G, Hobbs F, Kelley J, Den Lepcha S, Dong D, et al. Creating technology enriched activities to enhance middle school students' interest in STEM. In: Theo Bastiaens J, editor. Proceedings of the EdMedia innovate learning. Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE); 2019. p. 1344–52. Retrieved, https://www.learntechlib.org/primary/p/210144/.
[10] Cobb P, Confrey J, diSessa A, Lehrer R, Schauble L. Design experiments in educational research. Educ Res 2003;32(1):9–13.
[11] Cresswell JW, Cresswell JD. Research design: qualitative, quantitative, and mixed methods approaches. SAGE; 2018. Fifth Edition.
[12] Dalton EM, Roush SE. Assistive and educational technology standards and teacher competencies in relation to evidence-based practice: identification and classification of the literature. J Spec Edu Technol 2010;25(2):13–30.
[13] diSessa AA, Cobb P. Ontological innovation and the role of theory in design experiments. Journal of Learning Sciences 2009;13(1). 10.1207/s15327809jls1301_4.
[14] Donnelly-Hermosillo DF, Gerard LF, Linn MC. Impact of graph technologies in K-12 science and mathematics education. Comput Edu 2020;146. Retrieved from, https://www.sciencedirect.com/science/article/abs/pii/S036013151930301X.
[15] Dinçer S. Are preservice teachers really literature enough to integrate technology in their classroom practice? Determining the technology literacy level of preservice teachers. Edu Inf Technol 2018;23(6):2699–718.
[16] Ferrari A. DIGCOMP: A framework for developing and understanding digital competence in Europe. JRC scientific and policy reports. Eur Comm 2013. Retrieved from, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC83167/lb-na-26035-enn.pdf.
[17] Foulger TS, Graziano, Schmidt-Crawford DA, Slykhuis DA. Teacher educator technology competencies. Journal of Technology and Teacher Education 2017;25(4):413–48.
[18] Gravemeijer K. Educational development and developmental research in mathematics education. Journal for Research in Mathematics Education 1994;25(5):443–71.
[19] Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In K. Gravemeijer. J. van den Akker, S. McKenney, & N. Nieveen (Eds.), Educational design research (pp. 17-51). London: Routledge.
[20] Gravemeijer K, van Eerde D. Design research as a means for building a knowledge base for teachers and teaching in mathematics education. Elem Sch J 2009;109(5):510–24.
[21] Green LS. Through the looking glass. Knowl Quest 2014;43(1):36–43.
[22] Hakverdi-can M, Dana TM. Exemplary science teachers' use of technology. Turk Online J Edu Technol 2012;11(1):94–112.
[23] Hamilton ER, Rosenberg JM, Akcaoglu M. The substitution augmentation modification redefinition (SAMR) model" a critical review and suggestions for its use. TechTrends 2016;60:433–41.
[24] Hohlfeld TN, Ritzhaupt AD, Barron AE. Development and validation of the student tool for technology literacy. J Res Technol Edu 2010;42(4):261–89.
[25] Holloway I. AZ of qualitative research in nursing and healthcare. Wiley-Blackwell; 2008.
[26] Hokanson B, Gibbons A. Design in educational technology: design thinking, design process, and the design studio. New York, NY: Springer; 2014.
[27] Hughes J. Teaching english with technology: exploring teacher learning and practice. ProQuest Dissertations and Theses; 2000. 2000ProQuest Dissertations & Theses (PQDT.
[28] Hughes J, Thomas R, Scharber C. Assessing technology integration: the RAT-replacement, amplification, and transformation-framework. In: Crawford C, Carlsen R, McFerrin K, Price J, Weber R, Willis D, editors. Proceedings of the SITE-society for information technology and teacher education international conference. Orlando, Florida, USA: Association for the Advancement of Computing in Education (AACE). Retrieved August 23, 2020 from; 2006. p. 1616–20. https://www.learntechlib.org/primary/p/22293/.
[29] Instefjord EJ, Munthe E. Educating digitally competent teachers: a study of integration of professional digital competence in teacher education. Teach Teach Edu 2017;67:37–45.
[30] ISTE. National educational technology standards for teachers: second edition. Eugene, OR: ISTE; 2008.
[31] ISTE. ISTE standards for students. International society for technology in education. ISTE; 2016. Retrieved from, https://www.iste.org/standards/for-students.
[32] Kafyulilo A, Fisser P, Pieters J, Voogt J. ICT use in science and mathematics teacher education in Tanzania: Developing technological pedagogical content knowledge. Australas J Edu Technol 2015;31(4):381–99.
[33] Kessler G. Technology standards for language teacher preparation. In: Farr F, Murray L, editors. The routledge handbook of language learning and technology. London: Routledge; 2016.
[34] Kim C, Kim MK, Lee C, Spector JM, DeMeester K. Teacher beliefs and technology integration. Teach Teach Edu 2013;29:76–85.
[35] Kim MK, Xie K, Cheng SL. Building teacher competency for digital content evaluation. Teach Teach Edu 2017;66:309–24.
[36] Koehler MJ, Mishra P. Introducing TPACK. In american association of colleges for teacher education committee on innovation & technology. Handbook for technological pedagogical content knowledge. New York: Routledge; 2008. p. 3–29.
[37] Ilomäki L, Lakkala M. Digital technology and practices for school improvement: Innovative digital school model. RPTEL 2019;14(7). https://doi.org/10.1186/s41039-019-0099-y.
[38] McKnight K, O'Malley K, Ruzic R, Horsley MK, Franey JJ, Bassett K. Teaching in a digital age: How educators use technology to improve student learning. J R Technol Edu 2016;48(3):194–211.
[39] Novak E, Mulvey BK. Enhancing design thinking in instructional technology students. J Comput Assist Learn 2020. https://doi.org/10.1111/jcal.12470. Retrieved from DOI:.
[40] OECD. OECD skills outlook 2013: first results from the survey of adult skills. Paris: OECD; 2013.
[41] Olofsson A, D, Lindberg FO, Fransson G, Hauge TE. Uptake and use of digital technologies in primary and secondary schools: a thematic review of research. Nord J Dig Lit 2011;6(4):207–25.
[42] Oskay ÖÖ. An investigation of teachers' self efficacy beliefs concerning educational technology standards and technological pedagogical content knowledge. J Math Sci Technol Edu 2017;13(8):4739–52.
[43] Ottenbreit-Leftwich AT, Glazewski KD, Newby TJ, Ertmer PA. Teacher value beliefs associated with using technology: addressing professional and student needs. Comput Edu 2010;55(3):1321–35.
[44] Ozcan, M. (2013). Okulda universite: Turkiye'de ogretmen egitimi yeniden yapilandirmak icin bir model onerisi. Istanbul: TÜSIAD-T/2013-12/543.
[45] Papavlasopoulou S, Giannakos MN, Jaccheri L. Exploring children's learning experience in constructionism-based coding activities through design-based research. Comput Hum Behav 2019;99:415–27.
[46] Puentedura, R. (2009, February 4) As we may teach: Educational technology, from theory into practice [Blog] Ruben R.Puentedura's Weblog Available online at http://www.hiasuscom/rrpweblog/archives/000025html.
[47] Pulham E, Graham CR. Comparing K-12 online and blended teaching competencies: a literature review. Distance Edu 2018;39(3):411–32.
[48] Rahman MH, Schimpf C, Xie C, Sha Z. A computer-aided design-based research platform for design thinking studies. J Mech Des 2019;141(12). https://doi.org/10.1115/1.4044395. Retrieved from.
[49] Schrum L, Levin BB. Teachers' technology professional development: lessons learned from exemplary schools. Techtrends 2013;57(2):38–42.
[50] Shanmugam K, Balakrishnan B. Motivation in information communication and technology-based science learning in Tamil schools. J Pendidik IPA Indones 2019;8(1):141–52.
[51] Simsek O, Yazar T. Education technology standards self-efficacy (ETSSE) scale: A validity and reliability study. Eurasian J Educ Res 2016;63:311–34.
[52] Skoretz YM, Cottle AE. Meeting International society for technology in education competencies with a problem-based learning video framework. Computers in the Schools: Interdisciplinary Journal of Practice, Theory, and Applied Research 2011;28(3):217–22. https://doi.org/10.1080/17439884.2020.1773852.
[53] Strauss A, Corbin JM. Basics of qualitative research: techniques and procedures for developing grounded theory. 3rd ed. Thousand Oaks, CA: Sage; 1998.
[54] Tondeur J, Kershaw LH, Vanderlinde R, Van Braak J. Getting inside the black box of technology integration in education: teachers' stimulated recall of classroom observations. A*ustralas J Educ Technol* 2013;29(3):434–49.
[55] Tondeur J, Van Braak G, Voogt J, Fisser P, Otten-Leftwich A. Preparing preservice teachers to integrate technology in education: A synthesis of qualitative evidence. Computers & Education 2012;59(1):212–23.
[56] Twining P, Raffaghelli J, Albion P, Knezek D. Moving education into the digital age: the contribution of teachers' professional development. J Computer Assist Learn 2013;29:426–37.
[57] Uerz D, Volman M, Kral. M. Teacher educators' competencies in fostering student teachers' proficiency in teaching and learning with technology: an overview of relevant research literature. Teach Teach Edu 2018;70:12–23.
[58] U.S. Department of Education, Office of Educational Technology. Reimagining the role of technology in education: national technology plan update. Washington, D.C.: Retrieved from; 2017. https://tech.ed.gov/files/2017/01/NETP17.pdf.
[59] Zakharov W, Strobel J, Diefes-Dux HA. Teacher level factors and student achievement in a cyber-enabled engineering education professional development program. Int J Res Edu Sci 2020;6(1):48–60.
[60] Zydney JM, Warner Z, Angelone L. Learning through experience: using design-based research to redesign protocols for blended synchronous learning environments. Comput Edu 2020;143. doi.org/10.1016/j.compedu.2019.103678.