Ecological Approach to Technology Integration: A Comparative Analysis of Technology in Collaborative Learning Environment

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Abstract: With the increasing use of diverse technologies among K-12 learners the process of technology integration needs to be revisited. In this study we take an ecological approach to understand the impacts of technology on learning by conducting systemic analysis of tradeoffs associated with technology use on multiple learning outcomes. By analyzing student interactions, we examine productive and unproductive talk around different types of technologies. Our findings present quantitative and qualitative data to understand the distribution and nature of different types of talk around different technologies. We conclude the study by discussing the learning outcomes that different technologies supported and the need to take an ecological approach towards technology integration.

Introduction

The increasing use of diverse technologies among K-12 learners is posing newer challenges for educators as they integrate technology to achieve learning goals. Technology integration goes beyond the idea of acquiring technology for improving learning, to considering technology as a means for achieving complex learning goals outlined in the curriculum (Kimmons & Hall, 2016). This requires educators to focus on designing effective learning environments that consider technology's affordances in the context of overall learning goals, rather than studying its impact on singular aspects of learning.

With the rapid growth in the investment and acquisition of technology for K-12 learners, there is a need to understand the systemic changes that the use of technology is triggering in the learning environment (Alexander et al., 2019). Research has shown that technology plays a peripheral role in the process of learning, as compared to teaching pedagogies (Chauhan, 2017; Stahl et al., 2006). However, technology is a powerful mediation tool, which when integrated comprehensively within pedagogy, can transform the learning process. Hence redesigning learning spaces, to integrate technology-based teaching practices, has been central to researchers in the last decade (Jeong & Hmelo-Silver, 2016; Kirkwood & Price, 2014). A deeper analysis of the impacts of technology on learning is critical to CSCL contexts, where much of the work thus far has focused on presenting narrow, positive domain learning outcomes rather than a systemic analysis of tradeoffs associated with technology use on multiple learning outcomes (Borge et al., 2020). Towards that goal, the current study attempts to understand the scope, limitation, and nature of digital screen-based technologies within a collaborative learning environment, in comparison to physical technologies. The overarching research questions that the study aims to answer are, *RQ1: How are different types of talks distributed across screen and physical technologies within a design based informal learning environment?* And *RQ2: What do different types of talk look like around physical and screen technologies?* Through RQ1 we intend to understand the general trend of how different types of talk are distributed around different technologies. Using the findings from RQ1, RQ2 will dive deeper into the types of talk around physical and screen technologies to unpack the characteristics of two technologies that help and hinder collaborative and other aspects of learning.

Considerations for Technology Integration

Technology innovations, in terms of designing and developing new digital tools, are far ahead compared to the process of technology integration in the learning environment (Adkins, 2020). Technology integration is a means to enable technological innovations to lead to desired learning outcomes. It is a process that goes beyond acquiring and installing technological devices in the classroom and focuses on adapting the entire learning experience, to the use of technology, to achieve multidisciplinary learning goals (Bauer & Kenton, 2005). To do so, it is important to understand the strengths and weaknesses of technology, that goes beyond its utility as a product i.e., it's design and features, to understanding the social processes that it elicits in the learning environment. Hence, technology needs to be conceptualized as a tool that affects and is affected by the learning system. Having established this dynamic relationship between technology and the learning system, technology integration needs to be viewed as a holistic nested process that studies the learning system as a whole and not as multiple individual learning outcomes (Rose et al., 2017, Stahl et al., 2006).

The need for this dialogue emerges from the rapidly growing use of technology in K-12 learning environments without conclusive arguments about technology's impact on learning among children. On one hand, school districts like Liverpool Central School district in New York, Unified School district in California and many others, invested heavily in installing one-to-one technology and then terminated them because the programs did not result in any improvements in learning (Carr & Gibbs, 2012; Rockwell, 2015). Ravizza et al. (2017) further claim that nonacademic use of technology negatively impacted students' performance in their study. On the other hand, Manor New Technology High School in Texas has shown exceptional growth in student achievement and development of 21st century skills as they incorporated technology within a project-based learning approach. Integration of technology in several cases has shown to improve attendance, enhance student engagement, and reduce behavior problems (Chen et al., 2012; Hamilton-Hankins, 2017). Technology can either revolutionize education or lead to huge investments that yield very little returns. These conflicting findings along with rapidly changing landscape of education technology makes it challenging for researchers to draw definitive conclusions about the impact of technology on learning in K-12 learning environments. We cannot conclude that technology is a desirable or undesirable addition to the learning environment from these studies, but what they suggest is the need to ask systemic questions pertaining to technology's affordances. These contradictions tell us that we need to know the tradeoffs associated with our tools in relation to the learning ecologies within which they are embedded to make them yield more favorable learning outcomes. They also highlight the need to conceptualize learning more broadly to understand the tradeoffs of technology use on different aspects of learning (Borge & Mercier, 2019). Kimmons and Hall (2016) reviewed various technology integration models and concluded that technology adoption is still arbitrarily decided because of the existence of diverse models that have little in common. Hence, several researchers (Evans et al., 2011; Veletsianos, 2016) call for technology integration models that approach the process from a nested, systemic perspective where the role of technology is studied in relation to factors like curriculum, teaching pedagogies, learner's needs, and the learning goals.

Towards that goal the current study attempts to understand technology integration from an ecological perspective by studying the learners at the small-group and the community level in relation to different types of learning. Although learning is primarily defined as a collaborative process, other aspects of learning are also explored. Given the multidisciplinary nature of the study, where technology, learning, and collaboration are studied in relation to each other, we take a pragmatist perspective in building the theories to ensure that the complexity of the system is well represented. Using the sociotechnical ensemble theory, we conceptualize technology as a system that incorporates both technical and social aspects of working with technology (Bijker, 2010). Taking a sociocultural perspective, learning in our context is defined as a collaborative process of co-constructing knowledge by engaging in collective sense-making activities (Roschelle & Teasley, 1995). To further study the interaction of technology and learning, we use Hooper and Rieber's (1995) adoption model that emphasizes on the idea that one needs to go past the *familiarization* and *utilization* phases to get to *integration*, where important task-related functions are designated to technology. These changes would then lead to *reorientation* and *evolution* phases. The reorientation and evolution phases in their model emphasize on learner's active construction of knowledge as they use technology, bringing the learner's experience to the forefront. Finally, we use the design education theories to design the learning environment (Dym et al., 2005). These theories facilitate the design of the learning environment and the analysis of the data.

Methods

Context and Population

The data for this study was collected from three afterschool clubs conducted at a charter school in northern US during Fall 2018. The goal of these clubs was to develop technologically enhanced informal learning environments for promoting design thinking among children between the age of 8 – 10 years using different technologies. The three afterschool clubs were conducted on Tuesday, Wednesday, and Thursday every week and enrolled 12 unique students who worked together in groups of three. They worked on a semester long design challenge of redesigning a local mall to meet the needs of children. Using different technologies at different design stages, they engaged in identical activities to go through a simplified design cycle of question, plan, create, and investigate.

Data Collection and Analysis

Video recordings of each 75-min lesson, from fifty lessons across the semester and three clubs were used as the primary source of data. Other sources of data included student artifacts and facilitator observations. The happenings of all the lessons were documented after each lesson and were used for systematically selecting comparable lessons and groups for analysis. Six groups (two from each day of the club), and one lesson from each design stage was included in the analysis. A total of 23 hours of video data was analyzed for the current study using mixed methods.

To analyze the distribution and nature of talk around physical and screen technologies, we created detailed content logs of the selected lessons. To organize the data in a meaningful way, each lesson recording is divided into 2-minute segments called an *instance* and the speakers and events for each instance are documented in adjacent columns. Using the evidence from the event description, level 1 analysis was conducted to identify what technologies were being used by the group and if they engaged in content-related and collaborative talk. Content-related talk referred to an exchange of information that facilitated the students to accomplish their design projects. Collaborative talk involved interactions where two or more students were exchanging and building on each other's ideas. Each instance of talk was further categorized as productive and unproductive. Since the goal of the learning environment was to promote design thinking and collaboration among students, productive talk referred to interactions that promoted these aspects of learning. An instance was counted as productive when it included at least one example of two or more students collaborating with each other about design content related ideas. An instance was counted as unproductive talk when the students were neither engaged in content-related talk nor collaborating with each other.

For conducting level 2 analysis, the videos were watched again by the first author to focus on the technology/collaboration related decisions that the groups were making during each instance irrespective of its category. During this process the analysis focused on unpacking the nature of talk in comparison to the group's use of technology by observing their verbal and non-verbal interactions. Both level 1 and level 2 analysis were audited by another researcher and conflicting instances were discussed with the research group.

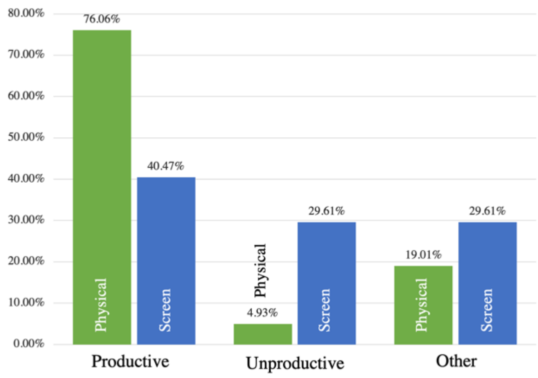
To understand the distribution of different types of talk across physical and screen technologies, the productive and unproductive talk categories were counted. To further understand the nature of productive and unproductive talk around digital technologies content logs were used to identify data "hotspots" for conducting interaction analysis (Jordan & Henderson, 1995). Once these hotspots were identified, case studies were developed using multimodal transcripts (Mondada, 2019) and microecological transcripts (Borge & Mercier, 2019).

Findings

RQ1: Distribution of types of talk around physical and screen technologies

From the quantitative analysis of instances across physical and screen technology, we found that the productive talk around physical technology was higher than screen technology (Figure 1). 76.06% of the total talk instances around physical technology were productive, as compared to 40.79% around screen technology. Consequently, the unproductive talk around screen technology was much higher in comparison to physical technology. 29.16% of the talk around screen technology was unproductive, as compared to 4.93% around physical technology. This initial distribution of the data provides evidence to suggest that physical technologies supported design content related collaborative talk more frequently than screen technologies. To further understand these differences, we discuss a comparative case from group 5 and 3, engaged in identical design activities using physical and screen technologies, to unpack the process of collective idea building. This case will shed light on the characteristics of physical and screen technologies that helped and/or hindered productive talk around different technologies.

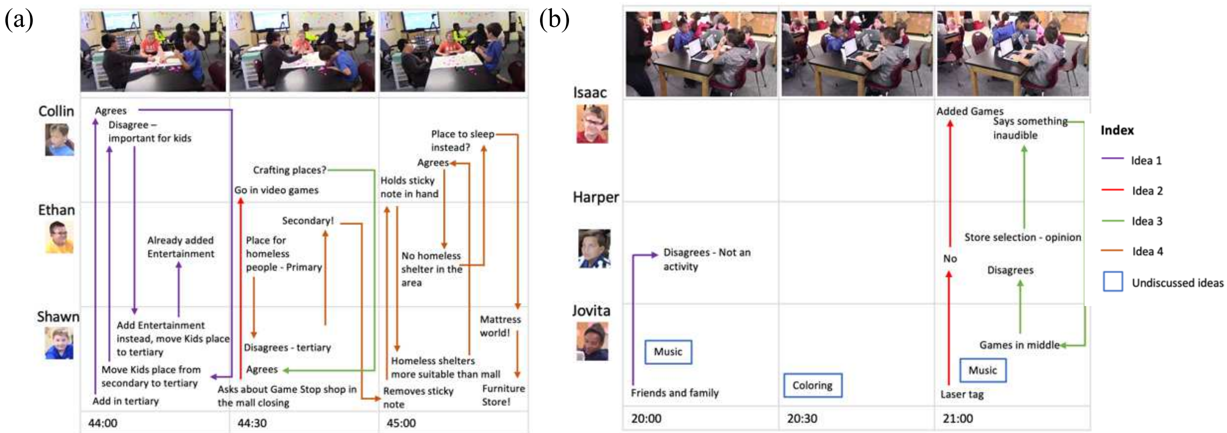
Figure 1. *Distribution of types of talk across all design stages around physical and screen technologies*



<u>Case 1: Comparative analysis of idea building process around physical and screen technologies</u>

Idea building was an important collaborative process that children engaged in during the question-plan stage of design. In the episodes we discuss below, group 5 using physical technology and group 3 using screen technology are creating a bull's eye diagram to prioritize the ideas that the group wanted to work on in the next design stage. Group 5 is using sticky notes and a shared poster to add and arrange ideas as per their agreed level of importance. Group 3 is doing the same activity using virtual sticky notes in a shared Google slide on individual laptops. The graphs shown in Figure 2 present a microecological analysis of turns taken to discuss an idea. The arrows show the movement of ideas between group members. The images on top show how the students positioned technology and were moving around it to build on each other's ideas.

Figure 2. *Microecological analysis of productive talk around screen and physical technology* **(a)** *Group 5 using physical technology for idea building* ***(b)*** *Group 3 using screen technology for idea building*



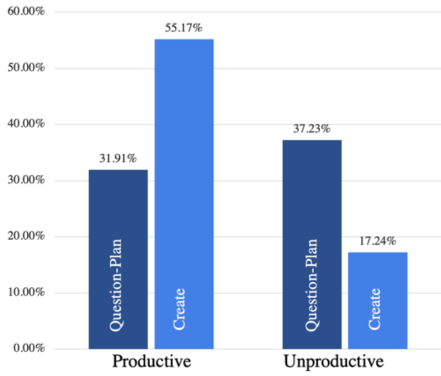
The process of idea building occurred differently around the two technologies. Around physical technology, students engaged with each other's ideas for longer turns of talk as compared to the screen technology, as observed by the density of arrows in Figure 2. Students using physical technology were able to explain their ideas using the shared artifacts on the table like charts, sticky notes, information pamphlets, etc. by pointing, annotating, and moving them around. Most ideas in the episode were discussed for 3-5 turns. Around screen technology, students struggled to understand each other's ideas and build on it. They often peeped into the other student's screen to see what they added, despite of being in the same presentation (see Figure 2b, timepoint 21). It was difficult for students to collaborate when the shared artifact was not a tangible object. As students were adding and arranging ideas in the shared slides, ideas presented by other students went undiscussed, for example music and coloring (timepoints 20, 20:30, 21).

When students engaged with each other's ideas for multiple turns, as it happened around physical technology, they were more likely to be aware of the collective group plan. When ideas were added to the group plan without being discussed, as it happened around screen technology, students were unable to make sense of the plan. In the post-activity reflection session, one of the students using screen technology, said "it was kind of difficult to eyeball everything" as they moved between slides, maps, and information pamphlets on the screen to create their plans. When technology was tangible, it was easier for students to engage in idea building, thereby reporting more instances of productive talk around physical technology as compared to screen technology.

RQ2: Understanding productive and unproductive talk

The initial analysis showed that there was more unproductive talk happening around screen technology compared to physical technology. It is critical to unpack the nature and purpose of different types of talk to understand the affordances of screen technologies and the learning experiences it fostered. Figure 3 zooms into the productive and unproductive talk around screen technologies at different design time-points i.e., question-plan and create stages of design. This analysis shows that the productive talk around screen technologies increased from 31.91% in the question-plan stage to 55.17% in the create stage, suggesting that screen technologies were more likely to support productive talk in the create stage of design as compared to the initial question-plan stage. To answer RQ 2 we further examine these two trends, by analyzing two episodes from group 1. First, from the productive talk category in the create stage to identify the characteristics of screen technologies that supported content-based collaborative talk in the create stage. Second, from the unproductive talk category in the question-plan stage to understand the types of learning screen technologies fostered.

Figure 3. *Distribution of productive and unproductive talk across all design stages around screen technology*



Case 2: Analysis of productive talk around screen technology

Figure 4 presents a case from the productive talk category when members of group 1 were creating a design prototype using screen technology. In this episode, all groups are creating the prototype in Minecraft using individual laptops. All students were building in the same shared server and each group had marked their building area. In this episode screen technology challenged students by creating a complex authentic problem that required them to collaborate as a community to solve the problem.

Figure 4. *An excerpt from Group 1's productive talk around screen technology from create stage*

1. L: Why is the water coming out of our house? **2.** B: Umm.. I don't know! Joey! What did you do Joey? **3.** J: I didn't do anything. Except I made some extra waterfalls.	**4.** B: I need a door. Umm.. how do you get a door? **5.** D*: They should be in the redstone section. **6.** J: Wow! People we have overflooded. **7.** L: Frida is on the way she is going to put a sponge down.	**8.** F*: Where are you? **9.** B: I cant stop the water. I cant. **10.** F*: Lance, where are you? Where are you guys? Are you guys underground? **11.** B: Yeah we are underground.	**12.** P*: I will help you if you need help. **13.** F: I see you. I see you. **14.** J: Guys, I know how to do it. **15.** L: There we go! There we go! This water should dry up now.

*Members from another group, B: Baylee, L: Lance, J: Joey, F: Frida, D: Derek, P: Pat

The episode started with Lance, from group 1, noticing water flowing out of the house they built next to the mall (line 1). Baylee, from group 1 asked her team member Joey if he did anything to cause the flooding (line 2). Joey accepts that he added a few extra waterfalls that might have caused the flooding (line 3). Group 1 promptly started thinking of ways to stop the water from flooding the nearby areas. Baylee tried to find a door to stop the water but did not know where to find it in Minecraft (line 4). Derek from another group overheard their conversation and helped Baylee find the door (line 5). In the meantime, Frida from another group told Lance that she will come over to their building area with some sponge to soak the water (line 7). Frida and Pat from another group try to locate group 1's building area in Minecraft (lines 8, 10, 12). Eventually, students from three different groups came up with strategies like using sponge, building doors, and digging the ground to stop the water from flooding the entire community.

The problem was complex because it required students to have a general awareness of the properties of water, apply that knowledge in the virtual environment, and know the technical steps in Minecraft to stop water from flooding the world. Students came in with different levels of expertise in Minecraft and hence often helped each other to learn more about the tool, which gave them the opportunity to collaborate with each other. Such collaborative episodes that emerged out of solving a technical problem in Minecraft were observed in every group when they were building in Minecraft. Minecraft, like other screen technologies, provided students with an open-ended learning environment where they were faced with complex authentic problems that required them to collaborate with each other and use creative approaches to solve them.

Case 3: Analysis of unproductive talk around screen technology

In the episode presented in Figure 5, Baylee, Joey, and Lance, members of group 1 were using laptops to create a plan of their mall's design. While using the laptop Lance opened the mall in Google maps to look up the stores. The need to open Google maps emerged from the initial idea of using maps to create the plan. However, the interactions in this episode were coded as unproductive because the group started exploring the features of Google maps without integrating the information in their plan. As they explore Google maps, they are observing each other but not actively exchanging or building on each other's ideas.

Figure 5. *An excerpt from Group 1's unproductive talk around screen technology from question-plan stage*

1. B: Umm the whole picture of it. Like the big picture. **2.** L: Here is the satellite view of it.	**3.** J: what did you type? What did you type? **4.** L: I am looking on.. This is Google maps. **5.** J: google maps? I will check	**6.** E*: What is this? **7.** B: He can actually travel anywhere. See like this. **8.** J: Ya I can now travel from the mall to Tennessee.	**9.** A*: Is that Google maps? **10.** F*: Yes! **11.** E*: That's amazing. **12.** F*: Ahaha.. There is Bonton **13.** E*: Buy stuff! Buy stuff!

*Members from another group, B: Baylee, L: Lance, J: Joey, E: Emily, F: Frida, A: Alan

In line 1 Baylee was intrigued by the Google maps view that Lance had on his screen and asks him to show her the bird's eye view of the mall. Lance in line 2 switches to the satellite view of the mall for Baylee. Later in the lesson, Joey peeps into Lance' screen to learn how to open Google maps (lines 3-5, image 2). These curious interactions were noticed by Emily who was a part of another group and walked over to group 1's table to see what they were doing (line 6, image 3). After Emily observed Baylee and Joey walking around the mall in Google maps and go all the way to Tennessee (lines 7, 8), she goes back to her group and explores Google maps with her group members (lines 9-13).

Throughout the interaction, Google maps and the laptop screen was in the center of the student's shared transactional space (see Image 1-4, green boxes). This engagement with the screen technology often distracted students from the design content but facilitated independent explorations around complex technologies. Members of group 1 learned how to use street and satellite view in Google maps without the facilitator's help and through observation, another group of students learned using these features as well, thereby helping them to develop fluency around digital technology.

Discussion

The goal of this study was to understand the impact of technology on different learning outcomes using systemic ecological approach. Although learning was defined collaboratively through the sociocultural lens for this study, we ensured that all kinds of learning that occurred in the environment, beyond the scope of the definition, were analyzed. We did so, by analyzing both productive and unproductive talk. Using the quantitative analysis to guide the qualitative exploration of narratives, we intend to conclude this study by synthesizing the affordances of physical and screen technologies and making recommendations about technology integration decisions for practitioners. We also intend to reflect on the idea of unproductive talk and reframe it to help educators broaden the scope of learning in informal learning environments.

Technology affordances

The analysis of productive and unproductive talk from the findings section suggests that physical technologies better supported the development of collaborative learning processes like idea building, negotiation, and sense-making as seen in case 1. Screen-based technologies, on the other hand, better supported the development of digital fluency skills like exploration, self-directed learning, and problem-solving as seen in case 2 and 3. We discuss specific characteristics of different technologies in the following sections to understand their impact on multiple learning outcomes.

Physical technology: Providing concrete and tangible learning objects

Physical technologies supported the development of idea building and sense-making among students as they facilitated complex design discussions through tangible shared learning objects like posters and sticky notes. As discussed by Stahl et al. (2006) and Streeck (2013), shared embodied experiences around learning objects foster intersubjective meaning making among learners. Students relied on gestures and visible body movements of their group members to understand the design idea that their team members wanted to propose. For example, children presented agreement for an idea with nods and thumps up; to express disagreement they would pick up the sticky note from the big poster and place it outside. These simple gestures communicated individual student's idea to the group and initiated negotiations among them. In contrast, around screen technologies children spent more time in understanding the origin of an idea and the technical steps involved in adding an idea into the shared space, dedicating lesser time to negotiating and idea building. These findings were supported by Burnett's (2016) research where learner and material positioning affected the way children collaborated with each other.

Screen technology: Providing open-ended learning environment

Although collaborative idea building was challenging for children around screen technologies, however, screen technologies were able to provide more sophisticated opportunities for developing digital fluency. Digital fluency is the ability to create new knowledge for solving problems by leveraging different types of technologies (Sparrow, 2018). The open-ended learning environment offered by screen technology allowed children to engage in independent exploration of online tools fostering self-directed learning around complex technologies. Self-directed learning is important in the age of information for promoting 21st century skills and lifelong learning (Geng et al., 2019; Trilling & Fadel, 2009). Moreover, the screen technology's open-ended learning environment often created unique authentic problems requiring children to work together to solve them. Learning opportunities like these fostered creative and critical thinking in real-time.

Reframing the unproductive talk

Given the goal of our learning environment, unproductive talk was defined as talk that did not support collaborative and design content learning. Across all design stages, screen technologies reported higher levels of unproductive talk compared to physical technologies. However, as we conducted a deeper ecological analysis, we discovered that although screen technology did not foster the skills that aligned with the goals of the learning environment, it fostered digital fluency skills that were relevant for the learners. This brings two important discussions in the forefront. First, screen technology's inherent ability to provide open-ended learning environment gives learners more autonomy to determine what they want to learn, thereby making screen technologies less suitable for achieving only predetermined learning goals. For screen technologies to thrive, learning goals must be defined more broadly beyond the scope of cognitive learning outcomes, to include sociotechnical, socioemotional, and metacognitive learning goals. As these learning goals emerge in the learning environment, they must be studied by taking a bottom-up approach. As a result, it is imperative for researchers to adopt systemic approaches to study the impact of technology on various learning outcomes by analyzing the predetermined learning outcomes and the learning opportunities that emerge in the learning environment. This is where we intend to reframe unproductive talk as unintended valuable learning experiences that emerge within the learning environment. The research within technology integration has been limited by the focus on studying the impact of technology on cognitive aspects of learning (Kirkwood & Price, 2014; Borge et al., 2020) and needs to innovate around the learning outcomes we study and how we study them.

Conclusion and future work

With this work we hope to shift the focus of technology integration from individual learning outcomes to the ecology of learning. In the process of focusing on the ecology, educators need to understand the tradeoffs associated with different technologies and learners need to be empowered to become active participants in the process of technology integration. This approach also gives learners the ability to design their learning experiences in relation to the technology and vice-versa, bringing learner agency, which is rarely discussed, in the process of technology integration (Tchounikine, 2019). Using these principles, our future work aims at developing a technology integration framework for educators.

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