RIDING THE WAVE OF EDUCATIONAL CHANGE

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Educators worldwide, from elementary school to university, have been faced with the necessity of teaching remotely during the COVID-19 pandemic. This situation is far from ideal for so many reasons that go beyond preparation for teaching with technology and student access to technology. However, we live, learn, play and work in a knowledge-based digital age, and now may be the ideal time to embrace technology as a component of everyday instruction. The question is, with so little preparation time will instructors be pulled down by the steep learning curve, or will they find new innovative methods of teaching? The availability of technology does not readily translate into better learning, nor does it replace teachers, but it can be designed to support, transform and extend learning for specific situations.

Technology as a Change Agent

Technology has long been considered a change agent for instruction. As early as the 1920's teaching machines were programmed to provide individuals with adaptive feedback based on specific individual responses (Pressey, 1920; Skinner 1956). Although the capability of these Skinner boxes was limited, the principles of individualizing instruction through technology was born. Since then we have witnessed a stunning growth in the power and portability of technology devices, along with theories that better explain how people learn in solo situations and in groups. Aligning technological innovations in education with theories of how students learn will result in better learning experiences.

The underlying mechanisms and design principles that dictate how learning and engagement can be enhanced in the context technology rich learning environments (TREs) have been the focus of continued research during the last decade. There are many kinds of TREs and they are created for different instructional purposes. In other words, they do not all provide the same features as some are created for solo learning while others can be used for collaborative learning situations. Although generalizable guidelines are still a matter of considerable debate, most learning scientists agree that there are several reasons that TREs can promote learning and engagement. We present these reasons below.

One-on-one Tutoring

Research has shown that one-on-one tutoring, be it human teacher to student (Bloom, 1984) or computer tutor to student (van Lehn, 2011), produce the highest learning gains when compared with one teacher to many students. The success of individualized tutoring is due to the dynamic context-specific nature of individualized feedback designed to help each student master their learning objectives. When designed appropriately, technology enhanced learning situations can embed nuanced assessments of learning. For example, Artificial Intelligence algorithms can be designed to help assess the underlying strengths and weaknesses in student learner profiles so that adaptive forms of instruction and feedback can be provided dynamically.

Multiple Representations

Technology can be used to represent complex ideas in multiple ways using multimedia (e.g., visualizations, simulations, videos and textual explanations) thereby helping make abstract ideas more concrete and understandable. Individuals learn through different means and thus one type of explanation may not be enough. Providing flexible alternatives can maximize one's reach to a variety of learner characteristics.

Models of Expertise

A primary goal of instruction is to help learners become more proficient or competent at something. Making the road to competence more visible can assist novices along their journey. For example, technology can provide exemplars that externalize models of proficiency for specific task performances and can make assessment criteria more transparent to learners. In this regard, students can observe and model their actions according to specific benchmarks that will help them along their specific learning trajectories. Importantly, technology can assist learners in becoming more autonomous and *self-regulated*, by helping them set goals, monitor and evaluate their performance and reflect on what they did or did not do well.

Deliberate Practice

It is important to note that not all practice makes perfect. To become more proficient, one needs to practice deliberately, which means getting the appropriate scaffolding needed to overcome errors or impasses (Ericsson, Krampe &Tesch-Romer, 1993). Technology rich learning environments can identify such errors and impasses and provide the needed feedback to learners in the context of these meaningful situations. In this way, students do not repeat "their mistakes or mis-steps."

Situating Learning in Cognitive Apprenticeships

Technology enhanced learning comes in many forms, from intelligent tutoring systems to immersive virtual reality simulations with pedagogical virtual agents. However, a powerful learning principal is to design such technologies to enable sustained practice in performing meaningful tasks. In other words, providing the learner experiences that help them practice skills through interactive activities that may mimic realistic situations. For example, students can become cognitive apprentices within specific domains of study where they have experts helping them participate in real-world practice activities. Thus, if students are learning science, they may engage in an immersive inquiry-based TRE where their goal is to use their scientific reasoning skills to identify why a phenomenon is occurring, such as, why the fish are dying in a particular lake. Such a TRE could provide scientific tools that help them formulate, report and test hypotheses by collecting and analyzing scientific evidence and thus improve their problem-solving abilities. Through such interactions, by directing their ideas, students are learning to learn on their own. However, they can also receive guidance from an expert pedagogical agent, when they ask for help, providing them with feedback that can help them solve the problem.

Collaborative Learning: Supporting Social Emotional Competencies

In addition to supporting individuals in their critical thinking, decision making, and problem-solving computers can also support social-emotional competencies and collaborative learning by fostering social skills, multiple perspective taking, active listening and communication skills. TREs can present opportunities for groups and teams to work on projects where shared goals are central to the successful completion of activities. Students can participate through text or through discourse depending on the platforms developed. Different technology features can be used to visualize student participation in the group and teachers can use such tools to intervene when teams are at an impasse, are dysfunctional or need more balanced participation. Promoting multiple perspective taking can lead to more innovative outcomes and greater well-being for participants when their voices are heard.

Enhancing Motivation

Technology rich learning environments can be motivating when they present students with optimal levels of challenges with problems that are neither too easy nor too difficult. When such environments are personalized, calling students by their name, and providing them some level of choice for certain features can help heighten their interest in a topic and enhance their perceived value of the activity resulting in more positive emotions and consequently more effort in the learning activity. Furthermore, certain TREs are motivating because there is degree of suspense in not knowing what will come next and there is a good balance of sensory stimuli that individuals enjoy. Learning by doing and interacting presents ongoing feedback to the learner which generally is motivating since the feedback is personalized.

Supporting Teachers in their Decision Making

Teachers are learners too and their decision to integrate technology into their teaching is influenced by their prior knowledge of, as well as confidence in, the value of technology tools. Accessing and deciding on what technology tools are beneficial for lesson planning can be daunting. However, teachers generally see value in tools that provide evidence of what students know and understand. Technology rich environments provide such evidence, primarily through records of student interactions while learning. These records are in the form of log files that record and assess the appropriateness of student actions in the context of problem solving. These traces present data on where students have learning impasses and misconceptions and teachers can use this data to inform their instruction. Trace data reveal the processes that students take to reach a solution and hence there is evidence of how they solved the problem in addition to the accuracy of their problem solving. These data reveal both formative and summative assessments that can inform teacher actions. Teachers can also make their own observations of students while they solve problems with technology on their own or in a group. When observing individual students use of a TRE the teacher might ask the student to think out loud while solving a problem, providing insight to the teacher regarding the student interpretation of the task. Technology platforms that facilitate collaborative learning can free up the teacher to observe groups in action, listening to (or reading) student discourse can help determine the quality of understanding along with the proportion of student participation, and scaffolding those groups that need assistance. When teachers observe from a

distance it might provide them with new insights into student understanding, seeing some students and their knowledge from a different perspective.

To conclude, not all TREs are the same. They have different instructional and assessment purposes. By considering the principles that guide our understanding of how learners learn best, technology usage could facilitate educational transformation to enhance the adaptability and efficiency of instruction. Currently, there are no provincial or national databases that list the types of technology enhanced learning environments that can be used for different grade levels and subjects. We can hope for these resources in the future but in the meantime teachers and parents can consider the above principles when evaluating the usefulness of specific software for educational purposes. As an example, I provide links to two creative technology environments, Crystal Island and Physics Playground, that embody the principles discussed in this article and that are available to educators, parents and students. Both are designed to help students learn science. Crystal Island is designed by James Lester and his colleagues to support middle grade students acquire science and literacy skills relevant to microbiology (http://projects.intellimedia.ncsu.edu/crystalisland/about/; (http://projects.intellimedia.ncsu.edu/crystalisland/getting-started/). In particular, students play the role of a medical field detective investigating a mysterious infectious disease outbreak affecting a team of scientists on a remote island. Students interact with virtual characters, virtual lab equipment, and read science texts to construct and apply context-specific knowledge to interpret complex events and formulate hypotheses as to what the disease is and what caused it. Physics Playground is designed by Valerie Shute and her colleagues (https://pluto.coe.fsu.edu/ppteam/) and supports students' understanding of qualitative physics in real-time. The game covers 9 key physics competencies (e.g., Newton's 3 Laws of Force & Motion) that students learn through creating and interacting with computer animated objects (i.e. ramp, lever, pendulum, and springboard) on the screen to test their theories about laws of force and motion and making physics learning fun. I have provided a link to other serious technology games showcased by the US department of Education that present different resources for different subject matter (https://www.edsurge.com/news/2018-01-10-what-we-learn-from-the-edtech-games-the-government-plays). Finally, the Journal of Information and Learning Sciences produced a special issue that presents different perspectives on remote-online-education that could be useful for those exploring these perspectives during this time of educational transition https://www.emeraldgrouppublishing.com/journal/ils/special-issue-free-access-a-response-emergency-transitions-remote-online-education.

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