Engaging Smart Instruction in Future Classrooms through the TPACK Framework

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Abstract

The role of instructors in current technology-invaded classrooms and the smart classrooms of the future continues to evolve as a result of technological developments. Educational technologies as essential parts of the education process is thus increasingly demanding a shift in focus from tools, to learners and their learning. Emerging educational technologies suggest smarter future classrooms, where learners' have high expectations of engagement with technology. Teachers' therefore need deeper understanding of how smart technologies integrate with pedagogies in content delivery to achieve effective learning. This describes SPELT or the 'smart pedagogies of learning technologies' or SPELT. In the technology-heavy classroom of the future, teachers must possess the knowledge of how the elements of content, pedagogy and technology interact to support smart instruction. The technological, pedagogical and content knowledge (TPACK) framework describes this interaction.This paper aims to highlight the significance of the TPACK framework for teachers' selection and design of learning technologies. This is discussed with focus on learner-centered, technology-based pedagogical approaches and those that explore the affordances of multisensory modalities. We also illustrate classroom implementation of TPACK using brief descriptions from two projects on the future of education. The teaching robot project describes 'education in the future classroom' taking advantage of peer learning while the Classroom on VR project describes virtual reality technologies taking advantage of multisensory instruction. The novelty of our work lies in the practical demonstration of how the philosophical notion of TPACK can be leveraged in the design of learning technologies to support smart instruction, in line with global and emerging trends in education. In addition, our description provides guidance to instructors who are not familiar with the TPACK concept.

Keyword: TPACK; Smart Instruction; Learning Technologies; Smart Pedagogy; Emerging Trends in Education

1 INTRODUCTION

PEDAGOGICAL science continues to evolve in the by the drastic changes being occasioned by emerging technologies. The effect on the role of various educational stakeholders as well as is also significant. Educational technology as an essential part of learning focuses on the learner by supporting the learning of content, application of technology skills, and the general process of teaching practice. It is further transforming the significance of concepts including the design of instruction and learning technologies. These changes are bringing learners more into their ideal roles as major stakeholders in the learning process and as being responsible for their own learning. However, the changes continue to place a demand for redefining education in terms of content, delivered by engaging the right technology and the appropriate pedagogy. All these must be integrated from the level of instructional design, and teachers/instructors must possess the required skills for the selection and implementation of classroom technologies within appropriate pedagogies for supporting content delivery. Engaging a standard framework that captures the interaction of the three classroom elements of content, pedagogy and technology in twentyfirst century education therefore becomes an ideal approach to guide teachers.

The Technological, pedagogical and content knowledge (TPACK) framework is a standard framework for implementing educational technology. TPACK has been reported in many studies as an effective framework that captures the complex relationship between content, pedagogy and technology. Its significance in the smart education of twentyfirst century, captured within practical design and implementation of classroom technology is however scarce. Engaging smart technologies within smart pedagogies for effectively delivering content is what we describe as the 'smart pedagogy of learning technologies', or SPELT, and represents the focus of this paper. We focus on the place of the TPACK framework in achieving this, with learners' interest as the central focus and the employment of pedagogies that explores the multiple advantages of novel technologies for delivering content effectively.

We focus on the engagement of learnercentered, technologybased pedagogies and those leveraging multisensory modalities as critical for effective instruction, based on the continual increase in the number of learning technologies supporting these possibilities and the proven ability of the techniques to promote effective instruction.

We address three specific objectives including a discussion of the significance of i) the concept of 'smart pedagogy of learning technologies'; ii) engaging TPACK within peer teaching iii) engaging TPACK within multisensory instruction and iv) a demonstration of how we implemented this approach through brief descriptions of two projects focused on 'the future of education'. Our overall aim is to show not only how the philosophical notion of TPACK can be leveraged in the design and selection of learning technologies to support smart education, but also, how the 7 elements can be integrated and employed in the design of learning technologies for the future classroom. Our presentation and argumentation lies within the context of, and are based on, the concept of global and emerging trends in education, and the opportunities and challenges presented for sustainable learning.

The rest of this paper is divided into four sections, the section provides a review of the literature on key concepts captured in the work including the challenges of technology use within education, the TPACK framework, its components and significance, the concept of smart pedagogy of learning technologies, and the theoretical foundations of the two approaches focused in this work. In section 3, we describe how the concept of 'smart pedagogy of learning technologies' was implemented through TPACK in the development of two education applications including a robotic instructor system and a virtual reality classroom system. The last section provides a brief discussion of the theoretical and practical implications of our work for instructional designers and facilitators in the future 'classroom'. The paper ends with a summary, a conclusion and suggestion for future works.

2 LITERATURE REVIEW

This section provides a review of the literature on key concepts captured in the work including the challenges of technology use within education, the TPACK framework, its components and significance, the concept of smart pedagogy of learning technologies, and the theoretical foundations of the two approaches focused in this work.

2.1 Technology Use in Learning: Challenges

Learning with technology is exemplified in many theories [1]–[4]. However, the rapid rate at which novel technologies make their appearance in current learning leaves no breathing space for instructor mastery. This is a major challenge with technology use within educational contexts. Software design is another challenge. Most tools are created as solutions to corporate business needs, rather than as solutions to pedagogical challenges, and are only adapted for classroom use. As such, design processes engage the viewpoint of programmers and developers, rather than those of instructors or instructional designers, and learners' interests are therefore not at the heart of most designs. These tools are usually contextneutral, and integrating them into learning assumes a uniformity in teacher personality, preferences, and ultimately, in engagement with technology. This presents serious challenges in learning, which is a contextual process. Addressing this requires some measure of proactiveness on the part of instructors, demonstrated in selection and design of learning technologies. Other issues include the emphasis on tools, rather than on ow to use it to support learning. This is reflected in the presentation of a daunting variety of tools with no standard plan for supporting teacher's engagement and mastery. Since instruction is not meant to be a trialanderror procedure, the need for clear focus, based on a standard framework to support the concept of SPELT becomes critical.

2.2 The TPACK Framework

The technological, pedagogical, and content knowledge (TPACK) framework was informed by appropriate learning philosophies, and it has been described as a standard framework for the purpose of understanding the complex interaction between classroom elements. However, not much is available in practical terms on how TPACK can support SPELT by focusing on every step from conception through design to classroom implementation stages.

TPACK has a precursor in Shulman's pedagogical content knowledge (PCK) framework [2] which describes the complex relationship between content and pedagogy at a time when the current technological pervasiveness of human life, society and the classroom was not the norm. Though learning technologies have always been part of education, previous tools have been rendered transparent, that is, they have become so familiar that the 'tech' in the technology is no more obvious. In recent times, a range of novel digital technologies have found their way into the classroom and into educational discourse, placing a demand for mastery on instructors.

The TPACK framework builds on Shulman's, extending it to the phenomenon of teachers' integration of technology into pedagogy. It describes how teachers' understandings of the three classroom elements of technology, pedagogy, and content can interact to produce effective disciplinebased and technologyaided instruction (AACTE, 2008). TPACK insists that the most effective form of learning with technology is based on a philosophy that the three elements do not exist as standalone concepts, but interact as pairs and as a whole. TPACK identifies 7 elements that include the interaction of these elements, capturing seven components including the 3 basic of content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). CK being knowledge about subject matter, while PK captures deep knowledge about the processes, practices or methods of teaching and learning, and how it encompasses, overall educational purposes, values, and aims. TK focuses on knowledge about traditional and more advanced, novel and emerging technologies including the skills required to operate particular technologies. The pairwise interaction of these elements yield 3 other elements including pedagogical content knowledge (PCK), technological content knowledge (TCK) and technological pedagogical knowledge (TPK) with TPACK as the interaction of all three elements making the seventh. Figure 1 shows the 7 elements of TPACK. PCK refers to knowledge of pedagogy that is applicable to the teaching of specific content, and includes knowing what teaching approaches fit a specific content, and how elements of the content can be arranged for better teaching.

TCK captures the manner in which technology and content are reciprocally related. Although technology constraints the kinds of representations possible, newer technologies often afford newer and more varied representations and greater flexibility.

Teachers need to know, not just the subject matter they teach, but also the manner in which the subject matter can be changed by the application of technology. TPK is the knowledge of the existence, components, and capabilities of various technologies as they are used in education, as well as how using particular technologies might impact the instructional process.

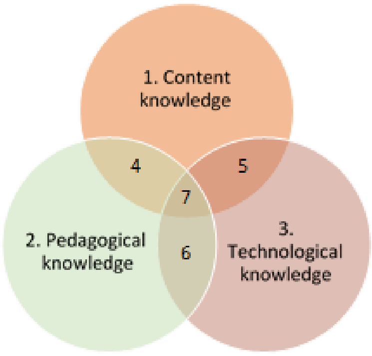

Figure 1: TPACK Framework showing the 7 Elements

TPACK brings together all these concepts and represents the form of knowledge that expert teachers should possess (whether this is obvious as with novel technologies or not, as with transparent technologies) and requires teachers to reconfigure their understanding of technology as well as of the three components.

Implementation of the TPACK framework has been reported in observation studies of faculty development and technology integration [3], [4] with emphasis on how TPACK informs and guides the integration of learner needs and characteristics as significant factors in the design of instruction. TPACK as an analytical tool has also been reported [5], with qualitative findings emphasizing the themes of technology, pedagogy, and content as co-dependent rather than independent constructs.

2.3 Theoretical Foundations of Peer Instruction

Peer Instruction (PI) has its foundation in active learning theories [9], [10]. Rusbult [11] describes learning situations that supports active learning to include learning from others, learning by discovery and learning by doing. He submits that, we learn most from others, with collaboration and communication being key to the learning process. We focus on a formal description of PI by Mazur [9], as a process whereby learners engage in knowledge sharing as a means of encouraging understanding, and improving learning through teaching others. It engages learners to share thoughts on a learning material based on personal understanding, and thereby benefit from peer as well as personal reviews [12]. Formal PI engages technology as a means of fostering motivation, engagement and deeper learning through students' responses which are collected by various means. The effectiveness of peer instruction has been reported in various subjects [13]–[16].

Two relevant concepts in peer instruction, related to the concept of 'pedagogy of learning technologies' are the use of conceptual questions (ConcepTests or CTs), and 'voting' or student response, which leverages classroom response systems (CRSs). Voting is based on students' choice of answers to the CTs. The place of technology is exemplified in the use of CRSs which in modern classrooms are handheld electronic tools or digital platforms which focus on promoting students' interest, motivation and improved classroom atmosphere which increases engagement.

2.4 Theoretical Foundations of Multisensory Instruction

Information processing by humans is understood from diverse cognitive perspectives including schema [6], levelsofprocessing [7], dualcoding [8], and stage [9] theories, addressing effective learning from various dimensions. The dualcoding theory recognizes multiple processing of information, but does not capture the whole extent of other possibilities with multisensory modalities. We argue for an extended idea of information processing involving multiplecoding beyond the visual and auditory senses. We specifically address 'haptics' or the sense of touch' as a significant aspect of learner perception that begins early in life, and even prior to the extensive development of the auditory and visual senses.

3 SMART PEDAGOGY OF LEARNING TECHNOLOGIES (SPELT)

The TPACK framework focuses on supporting of teachers to harness the almost infinite uses to which computer and other novel technologies can be put for mor effective classroom practice [10]. There are tool-induced constraints on content, including the nature of possible representations which sometimes place undue constraints on instructional moves and other pedagogical decisions. 'Smart Pedagogy of Learning Technologies' (SPELT) refers to the complex relationship of technological knowledge and pedagogical and content knowledge and how they integrate in the process of developing good instruction.

Gibson [11] describes the 'pedagogy of learning' (PoL), a similar concept to PCK [2], and a contradiction intended to suggest a reduction of emphasis on the teaching process in favour of emphasis on learning. Gibson proposes a position whereby individual learner's needs drive the instructional process. Similar to Gibson, through SPELT, we intend to suggest a reduction of emphasis on the exclusive place of technology in the teaching process, in favour of emphasis on the learning that it is intended to promote. SPELT is thus, a call to look away from trending tools, technologies, gadgets and the best pedagogical approaches, to focusing on learner's needs and learning. We emphasize that 'knowing how to use technology is not the same as knowing how to teach with it'. SPELT can guide system design and the creation of coherent learning environments. Following, we describe the development of two learning technologies in the context of smart classroom systems, and how SPELT is integrated using TPACK in their design. As we developed the teaching systems, we pursued the idea that the design of learning technologies should be driven by learners' needs and the achievement of effective learning. We specifically focused on two approaches that have been emphasized in education, and which has persisted through the decades;

these are peer teaching, and multisensory instruction. We describe a robotic instructional system based on peer teaching and a virtual reality learning system based on multisensory instruction to illustrate our concept of SPELT.

4 IMPLEMENTING SMART INSTRUCTION IN THE DESIGN AND SELECTION OF LEARNING SYSTEMS

4.1 The Robotic Teacher System

Inspired by possibilities of nonhuman teachers in the smart classroom of the future, and based on capabilities already demonstrated by machines, and trends in artificial intelligence, robotics and internet accessibility our team developed a robotic instructional system that engages learners in the STEM classroom. In line with TPACK, the system was based on the PI pedagogical approach, thereby removing the focus from the 'teacher' to learners in the learningbyteaching procedure. The system focuses on extending the role of technology beyond serving as tools, to playing roles that parallels that of humans in tomorrow's classrooms while keeping the learner as the focus.

4.2 The Multisensory Classroom on VR (MCVR)

The MCVR integrates the advantages of immersive learning with audiovisual and tactile modalities in its design. We focused on the known effectiveness of e in the design of the system which is hosted in a VR environment on a PC or head mounted display (HMD) which enables the learning of structures of organic chemistry through a gamelike procedure for building basic hydrocarbon molecules. Learners are enabled to pick atoms to build molecules based on game rules that are standard rules of structures in organic chemistry. In the process, participants learn 'what works' and what doesn't. By introducing the gamelike approach, learners are motivated and engaged in the unconscious learning process. In addition, the procedure also enabled team or collaborative approaches to learning. The integration of TPACK approaches in the design of the two systems, highlighting the concept of SPELT, is shown in Table 1.

Table 1: Integration of TPACK Elements and SPELT in Learning System Design

	Knowledge Type and Description	Integrated TPACK Elements in the Learning Systems
1	Content Knowledge (CK): Knowledge of subject matter	Knowledge of basic science is the basis of instruction
2	Technological Knowledge (TK): addresses knowledge about standard, and emerging tools and the skills required to operate them	Focus on the robotics and VR; for supporting learner motivation, engagement, immersive and multisensory learning, and are adequate for science instruction
3	Pedagogical Knowledge (PK): Deep knowledge of the processes, practices or methods of teaching and learning & how it encompasses overall educational purposes	Selection of the learningbyteaching approach with the robotic instructor and learning through immersion, and multisensory modalities in the VR system.
4	Technological Content Knowledge (TCK): the manner in which technology and content are reciprocally related; varied representations and flexibility, and how subject matter can be impacted by application of technology. For example, a 3D system will be appropriate for teaching spatial relationships or orientations.	Content for the robot system was based on simple introduction to matter, element and symbols while the VR system focus on the structure of molecules as combnation of atoms. Though science contents are employed in both systems, specific content/topic were selected to match and maximize the affordance of the technology type
5	Pedagogical Content Knowledge (PCK): knowledge of pedagogy applicable to the teaching of specific content; of teaching approaches that fits a specific content, and how elements of the content can be arranged for better teaching	PI is not only ideal for promoting effective learning, it is also a learnerfocused approach that is ideal for a nonhuman facilitator by making the learner play the role of instructor. A multisensory approach to the teaching of building organic molecules is equally an ideal approach
6	Technological Pedagogical Knowledge (TPK): Employing knowledge about technology in selecting and using appropriate pedagogy.	Our focus is to prioritize the learner in the learning procedure; in both systems, the knowledge of robotics and VR systems were brought to bear in selecting the pedagogical approaches and the content being communicated;
7	Technological Pedagogical Content Knowledge (TPACK): knowledge that expert teachers should possess	A holistic teacher knowledge or TPACK is demonstrated in how CK integrates with TK in the use of robotics or VR and PK of the learningbyteaching and multisensory approaches for delivering science content

4.3 Theoretical and Practical Implications

The roles that machines and other nonhuman entities will play in the future classroom can only be imagined. As technological developments continue to be extensive, demands on teachers to upgrade their knowledge will increase and so will the type of skills required of them. The roles of teachers will become more and more that of classroom managers, facilitators of instruction, and codesigners of learning technologies. Skills on selection of appropriate tools for supporting learning will also be in high demand. As colearners in the future classroom, TPACK integrated in SPELT will serve as an ideal framework for effective teaching practice.

5 CONCLUSION

This paper focused on a demonstration of the important place of learning as the focus of technology use, pedagogical approaches and content development. We also highlight how the complex interaction between these elements can be engaged by the professional teacher. We wish to note that technological trends and developments will continue to create educational challenges, hence, teachers must keep uptodate, continuously learning and keeping abreast of global developments both in their fields and in the area of technology. The teachers' role will continue to evolve, placing a demand for skills and knowledge upgrade regarding novel technologies, content and pedagogical approaches ideal for different learning situations. We have augmented Gibson's [11] PoL with SPELT, and we hope that future research can also examine and expand the 'pedagogy of learning content' or 'pedagogy of subject matter' to complete the system.

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