Lecture Notes in Educational Technology

Ting-Wen Chang
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# Authentic Learning Through Advances in Technologies

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# Contents

# Part I
# Learning Design for Authentic Learning

# Improving Learners' Experiences Through Authentic Learning in a Technology-Rich Classroom

**Kaushal Kumar Bhagat and Ronghuai Huang**

**Abstract** Currently, bringing authenticity into the classroom is one of the biggest challenges faced by educators, instructors, and policymakers. How to make learning more meaningful, enjoyable an effective? How to construct authentic tasks within the classroom to improve learning? These are some important questions without clear answers. An authentic learning environment is one of the answers to the above questions. Incorporation of authentic learning with technology can make learning more interesting and interactive. The purpose of this chapter is to review the current status of authentic learning and discuss the applications of technology in developing authentic tasks. The various approaches to create authentic learning environment are discussed, as well as some empirical evidences are provided to support infusion of technology in authentic learning.

**Keywords** Authentic learning · Emerging technology · Technology-rich classroom

## 1 Introduction

In the twenty-first century, every sector of society is facing complex problems and challenges all around the world. Therefore, widespread efforts are needed to improve education systems to prepare the next generation to confront these challenges. For example, large data sets are now being collected in a variety of contexts; analyzing the data has become increasingly important as well as increasing challenging. As a result,

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mathematics has becoming an important tool in order to use in understanding everyday problems in living and working in the twenty-first century. The traditional focus memorizing facts and applying simple procedures are not sufficient for managing and making sense of large data sets. However, students are still asked to memorize formulas and some basic mathematical facts. Students are seldom taught why they need to know those formulas or how they can be applied to solve real problems. Effectiveness is short lived due to lack of practical and useful knowledge. This situation happens in other academic disciplines as well as in mathematics.

It is the solemn responsibility of the teachers to foster learners' reflective thinking and involved them in active learning. Children's lives at school should be linked to their daily life experiences outside the school. This will mark a departure from the bookish learning which continues to shape many education systems and, which creates gaps between schooling, working and living in modern society. Treating the prescribed textbook as the sole basis of knowledge and a guide for testing is one of the key reasons why other resources are ignored. Therefore, it is important for students to develop broad, transferable skills, and knowledge. There are four essential higher-order skills: (a) critical thinking and problem solving, (b) communication, (c) collaboration, and (d) creativity and innovation which are also referred to as twenty-first-*century skills* (see http://www.p21.org/); all four are needed as part of a complete and comprehensive education.

Currently, digital devices like mobile phones and tablets are very popular among students in schools and universities. These devices provide opportunities for ubiquitous learning allowing students to access information from any place at any time (Prensky 2001). Increase in integration of wireless network and emerging technologies, such as augmented reality (AR), virtual reality (VR), mixed reality (MR), in the classroom not only create new learning opportunities but also bring challenges for the instructional designers. AR is a computer generated 3-dimensional interactive environment which combines real- and virtual world (for example see http://newatlas.com/ikea-augmented-reality-catalog-app/28703/).VR technology is a computer simulation system that could create a 3D virtual world, representing real or non-real situations. The users will obtain an immersive experience and sense of presence by doing real-time interactions with the environment through head-mounted displays, hand, and body gestures (for example https://developers.google.com/vr/android/samples/vrview). On the other hand, MR is the hybrid of AR and VR and regarded as more advanced technology than AR and VR (see http://edutechwiki.unige.ch/en/Mixed_reality). The most significant challenge for schools and teachers is to create technology-rich classroom environments and design learning activities and sequences to meet the needs of the new challenges of the twenty-first century (Prensky 2001; Tapscott 1999).

For learners, effective learning strategies and support should be provided to make connections to existing knowledge and to explore new knowledge deeply in context in the way fitting their nature. Authentic learning is considered as one of the instructional approaches to guide the teaching and facilitate learning to bring real-world experiences inside the classroom (Banas and York 2014; Lombardi 2007). There have been many research studies to integrate authentic learning into teaching and learning (Amory 2012; Diamond et al. 2011; Herrington and Parker

2013; Herrington et al. 2014; Pu et al. 2016; Tabuenca et al. 2016). However, how to use technology to support authentic learning is still a big challenge for educators. Therefore, this chapter attempts to review different aspects of authentic learning and applications of different emerging technologies in making authentic learning more effective.

## 2 Authentic Learning

### *2.1 What Is Authentic Learning?*

"Authentic learning is defined as learning that is seamlessly integrated or implanted into meaningful, 'real-life' situations" (Howland et al. 2012, p. 5). Steve Revington (2016) defined authentic learning as "a real-life learning. It is a style of learning that encourages students to create a tangible, useful product to be shared with their world" (Revington 2016). Authentic learning provides the opportunity for the learners to explore and construct concepts, which are related and can be applied in real-world environment outside the classroom (Donovan et al. 1999).

Lam (2013) explained authentic learning as a pedagogical approach to engage the students in solving real-world problems. Role-playing, learning by doing, project-based learning, and problem-based learning, etc., are some of the learning activities, which are included in authentic learning activities. Some important benefits of authentic learning are: (1) boosts motivation; (2) better learning opportunities; (3) preparation for better future; (4) makes a complex concept easier to understand; and (5) blends theories with learning. According to Brown et al. (1989), authentic learning composed of coherent, meaningful and purposeful activities. To summarize, authentic learning, in terms of learning activity, is an instructional approach which allows learners to discuss, explore and collaborate to construct new knowledge and create new real artifacts in real-world settings and tasks.

### *2.2 Foundation of Authentic Learning*

Authentic learning is often guided by constructivism. It is not a new instructional approach (Lombardi 2007). It has been applied in some educational systems around several years ago. Constructivism is the theoretical approach which helps in building the knowledge by the learner himself/herself without the support of the instructor (Papert 1990). A constructivist approach provides the opportunity for the learners to collaborate with other peers and apply their existing knowledge to construct a new concept.

"I believe that the school must represent present life-life as real and vital to the child as that which he carries on in the home, in the neighbourhood, or on the playground" (Dewey 1987, p. 2). John Dewey argued that learners must be involved in the activities in which they can apply the concepts which they learn inside the classroom. He strongly believed the importance of experiences and logical thinking for the development of problem-solving skills. Imagination and real-life experiences are the important founding key elements of authentic learning. Learners should find a reason why he/she is learning any concept? How is he/she going to transform his conceptual knowledge into practical knowledge?

Authentic learning enables learners to manipulate the factors and observe different outcomes. It is not necessarily important to get positive results only. Sometimes contradictory results can also help the learner to develop reasoning and logical thinking. Finding scientific phenomena in the daily life activities can do the job of our teaching purpose. Learning should not only in the classroom, students must be motivated to develop scientific arguments right from their home. "The function of both an authentic learning environment and an authentic task is to show students relevance and stimulate them to develop competencies that are relevant for their future professional or daily lives" (Gulikers et al. 2005, p. 510).

## 3 Design Approaches of Authentic Learning

### *3.1 Cognitive Apprenticeship*

Before the emergent of formal schooling, apprenticeship approach was widely used to transfer knowledge and skills such as construction, painting, sculpting, law and medicine. Even today, many fields, especially those required expert skills, are using the traditional master–apprentice model to transmit knowledge and skills. Traditional apprenticeship was composed of three stages: modeling, coaching, and fading. Modeling refers to the stage in which expert will execute the skills, and learner will observe. In coaching stage, learner will practice the skills, and feedbacks will be provided by the expert to improvise his/her skills. In the final stage, learner will be independent and expert will reduce participation the learning-teaching process (Allan Collins et al. 1988).

Cognitive apprenticeship is a model of instructional approach that combines both apprenticeship and school environment to visualize the thinking process. Allan Collins et al. (1988) defined cognitive apprenticeship as "learning-through-guided-experience on cognitive and metacognitive, rather than physical, skills and processes" (p.3). Cognitive apprenticeship promotes active engagement of the learners in authentic tasks to find the solutions by themselves without any intervention. In this type approach, students are challenged to solve the realistic problems which are sometimes beyond their ability. This promotes higher-order reasoning skills (Dennen and Burner 2008). Students with their different ability level work together in the same learning environment to solve the challenging tasks which promotes inclusive education (Collins et al. 1991).

Dennen (2001) advocated the potentials of cognitive apprenticeship but also highlighted some of the challenges of using this approach. The challenges include handling large class size, diverse cultural background of the learners, time limit, and most important how to take care of each learner's personal needs. Teachers should be well-equipped and supported by the administration. Emerging technologies like Intelligent Tutoring Systems (ITSs) may answer these challenges and can help the teacher as a means of a scaffold for the students to demonstrate the skills and evaluate the skills learnt by the student.

### 3.2 Situated Learning

Situated learning theory was developed by Jean Lave, among others according to Lave and Wenger (1990), learning is a process of "legitimate peripheral participation." "Legitimate" refers to novice learners who have no expertise; "peripheral" refers to process of solving easy problems first and then to go for complex problems; and "participation" refers to practicing the knowledge which the participant gained during the whole process in the real-world context. Situated learning is very close to social-constructivism. Situated learning approach consists of two important components: (1) social, the collaboration or interaction between the learners to solve a problem and (2) authentic, the real world or activities provided to the learners. Young (1993) listed four important tasks for situated learning: selection of the situation, scaffolding, design to track the progress, and final is to design role of assessment.

Later, Herrington and Oliver (2000) designed a framework to define nine important key elements, which are needed to support situated learning: (1) authentic contexts that reflect the way the knowledge will be used in real life; (2) authentic activities; (3) provide access to expert performances and the modeling of processes; (4) provide multiple roles and perspectives; (5) support collaborative construction of knowledge; (6) promote reflection to enable abstractions to be formed; (7) promote articulation to enable tacit knowledge to be made explicit; (8) provide coaching and scaffolding by the teacher at critical times; (9) provide authentic assessment of learning within the tasks. Numerous previous empirical evidences support that situated learning environment is effective. For example, Kamarainen et al. (2013) developed an augmented reality-based system (Eco-MOBILE) to study ecosystem based on situated learning theory. Results revealed that students were engaged in the learning activities and gained deeper understanding about the water-quality metrics. Hung et al. (2015) integrated situated design (i.e., story and characters) into content-related body movements in the learning activity. In the situated embodiment-based learning group, learners not only gained the knowledge but also got the opportunity to apply what they learnt. Therefore, the results showed that situated embodiment-based learning group performed better than the embodiment-based learning group. This helped them to develop procedural knowledge construction. In addition, they found situated embodiment-based learning had lower their extrinsic cognitive load and enhance their attention. Chuang et al. (2015) created a situated spectrum analyzer learning platform based on situated learning theory. After using this system, there was significant improvement in the learning of the students. González-Marcos et al. (2016) applied situated learning theory in virtual team to examine its effect on satisfaction and learning outcome. Results showed that situated learning methodology was more effective than the tradition teaching approaches in terms of students' satisfaction and performance.

## *3.3 Problem-Based Learning*

The notion of problem-based learning came from John Dewey. John Dewey stated that "the first approach to any subject in school, if thought is to be aroused and not words acquired, should be as unscholastic as possible" (Dewey 1966, p. 154). Problem-based learning (PBL) is a student-centered instructional approach in which students learn the concept by solving an open-ended problem. Barrows and Tamblyn (1980) defined problem-based learning, as "the learning that results from the process of working toward the understanding or resolution of a problem" (p. 18). In PBL approach, problems are ill-structured, authentic, and real-based. These types of problems arise students to think critically and scientifically. Students act as self-directed learners or problem-solvers in small groups collaborating with other peers whereas teachers act as facilitator and monitor the whole learning process. PBL approach helps the learners to develop deeper thinking and skill development, which will be beneficial in the twenty-first century.

Polya (1957) proposed four principles in problem solving: (1) understanding the problem, involves identification of the unknown quantity. What are the conditions available? (2) devise a plan, involves identification of the strategy. What are the mathematical/scientific concept behind the problem? (3) carry out the plan, involves the application of the identified strategy. If it fails, then try to find another best approach and keep trying until it works and; (4) look back, involves the verification of the solution. Does the solution answer the question with right argument?

Previous research studies have shown the benefits of PBL approach. For example, Sahin (2010) investigated the effectiveness of PBL on students' epistemological beliefs and conceptual understanding of Newtonian mechanics. Although there was no significant difference between the experimental group and control group for epistemological beliefs but there was significant difference between the groups in terms of conceptual understanding. Another study (Liu et al. 2011) applied media rich PBL approach in science learning and examined its effects on students' motivation and science knowledge. They found that students' in the experimental group showed improvement in both science knowledge and motivation toward science learning. Tosun and Taskesenligil (2013) advocated that PBL approach helps the students in improving critical thinking and scientific processing skills (observation, classification, measurement, prediction, and deduction). Wijnen et al. (2016) investigated the effects of PBL approach in knowledge acquisition and knowledge retention for psychology students. They reported that PBL approach resulted in positive effect both on knowledge acquisition and knowledge retention compare to lecture based. They found that discussing realistic problems using PBL approach helped the students in the learning process. Jou et al. (2016) integrated mobile learning app with PBL approach to teach material synthesis. Results revealed that PBL approach improved learning performance of the students and also students showed positive learning attitude toward the use of mobile applications in teaching and learning. Gunter and Alpat (2017) examined the effects of PBL in on students' learning achievement in chemistry and found that students who were taught by PBL approach outperformed compared to the other group. In addition, they concluded that students' in the experimental had deeper understanding of the concepts as the problems were related with real-world scenarios.

## 4 Authentic Learning with Emerging Technologies

The main purposes of using technology in the classroom is: (1) to support learning environment or context; (2) design learning activity; (3) assessment; (4) act as cognitive tools to support learners to explore knowledge; (5) solve authentic, real-world problems and (6) mediate collaboration and communication (Howland et al. 2012; Jonassen et al. 1998). Applications of the Internet, visualization and simulation technologies can promote authentic learning experiences for the learners, which can help to make a bridge between the classroom learning and real-world (Lombardi 2007).

### *4.1 Application of Emerging Technologies in Authentic Learning Activities with Different Aspects*

"Technology is an integral part to accessing the higher-order competencies often referred to as twenty-first-century skills, which are also necessary to be productive in today's society" (see http://www.oecd.org). Veletsianos (2010) defined emerging technologies as the tools, technologies, innovations, and advancements applied in different educational contexts to support diverse education-related goals. Herrington and Parker (2013) considered emerging technologies as not only the medium for delivery mechanism or collaboration but also cognitive tools for thinking. Emerging technologies like Maker spaces, learning analytic, VR, and AR will be widely used in education (see www.nmc.org). In this section, some of the features are described, which can be supported by using these emerging technologies.

### 4.1.1 Connecting Real Life with Classroom Activities

Emerging technologies, such as mixed-reality technology, mobile device, robot and QR code, enable the creation of virtual reality context, professional networks or serendipitous learning context. For example, Bozalek et al. (2013) used the affordances of Google translator in an innovative approach to develop students' academic literacy, relating the activity to students' real-life practices and making it authentic and meaningful with their own lives. Chang et al. (2010) designed a system with authentic scenes by using mixed-reality technology and robot, which improved the sense of authenticity of the task and also positively affected learning motivation through experiment.

### 4.1.2 Authentic Task

Digital stories, simulation games, learning platform, and social media could help students to redefine the tasks and promote student motivation, creativity and collaboration.

### 4.1.3 Act as an Expert

Emerging technologies provide a lot of opportunities for learners to act as an expert to solve problems and share the narratives and stories through creating learning context or communities.

### 4.1.4 Multiple Roles

The facility of the Internet and social media enables learners to become content generators, which allows learners to voice their own concerns, express different ideas and talk stories from various perspectives, across both formal and informal learning contexts. The Anatomy Wiki project is a good example. In this project, students collated their research about the topic using the Internet and textbooks at first, and then created a wiki page about each topic with their own perspective and ideas (Titus 2014).

### 4.1.5 Reflection

Creation of student-generated social media e-portfolios, such as blogs, video and quizzes enables creation, critique, and reflection.

#### 4.1.6 Articulation

Emerging technology can provide a variety of collaborative presentation and interaction tools, such as videos, MindManager, Google docs, Prezi, and wireless screen mirroring. Skitch is a freely available mark-up tool which can be used in teaching mathematics. Skillen (2014) described many applications in mathematics such as illustration of fractions, understanding position in maps, tracing and highlight the angles in the given pictures, and finding different shapes.

#### 4.1.7 Coaching and Scaffolding

There are many emerging technologies such as robots, WeChat and MSN enable the nurturing of learning communities across varied contexts and gave the necessary supports for the learning.

#### 4.1.8 Assessment

Emerging technologies can seamlessly integrate assessment with the activities through collecting learners' performance information in authentic activities to form e-profiles and analyzing it to assess student learning. Technologies like Intelligent Tutoring System (ITS), feedback systems like clickers can provide immediate feedback and record the performance of the students for conducting longitudinal studies.

### *4.2 Learning Benefits of Authentic Learning in Technology-Rich Classroom*

In this section, some of the empirical evidences are presented to support the integration of authentic learning and technology for the benefits of the learners.

Pu et al. (2016) developed an authentic learning model using mobile technology for vocational nursing education. The results revealed that m-Learning system reduced workload for the students and promoted collaboration and interaction among the members of the group resulting in positive engagement and interactive discussions. On the other hand, teachers can track the learning progress of the nursing students. Chin et al. (2015) developed a QR-based U-Learning Material Production System (QR-ULMPS) to deliver course materials via mobile phones for college-level students. QR-ULMPS provided the opportunity for the learners to explore the learning content at their own pace. The results showed that students who used QR-ULMPS were highly motivated, satisfied, confident, and performed better than the control group.

In another study by Somyürek (2014), students were engaged to construct robot using LEGO Mindstorms NXT. Students were engaged in the active learning process by providing challenging tasks to be solved by the problem-solving method. In addition, students were allowed to learn by doing and learn. They need to play multiple tasks like making predictions, building hypothesis, presenting their thinking process to find the solutions. The results showed that students found this kind of activities more fun as they were allowed to present their imagination, which results in good motivation toward the learning process. These kinds of activities foster critical thinking. (Chen et al. 2013) developed a platform "Digital Learning Playground" (DLP) to solve real-life problems supported by robots. The results indicated better learning performance, engagement, and enjoyment of the learners. They advocated the use of technology in the conventional classrooms to make it authentic learning environment and educational robots could be one of the best solutions. McCaughey and Traynor (2010) studied the role of simulations in nursing education for undergraduates. Majority of the students found simulation as an authentic learning experience. They concluded that simulations provide student-centered and risk-free learning environment for the students. In another study (Sadik 2008), digital story telling approach was used to support authentic learning. Students were divided into groups and asked to develop digital story. Results showed that digital storytelling helped the teacher to enrich class environment by connecting with real world. In addition, it enhances the motivation and creativity skills of the students. Improvement in collaboration and communication skills with better understanding about the course content were other benefits of the digital story telling. Rowe et al. (2013) used Google Drive as a platform to execute authentic learning tasks. They found that it helped the students to develop critical thinking and students felt more authorized to regulate the learning process.

However, Gulikers et al. (2005) concerned about the effects of authentic learning environment. The results did not present any better results in comparison with non-authentic environment in terms of learning performance and motivation. They argued that students in the authentic learning environments can easily be distracted because of more irrelevant information and multimedia features.

## 5 Concluding Remarks

From this chapter, we can conclude that authentic learning has been integrated with different emerging technologies. These integrations have promoted best academic performance results. In addition, we found that authentic learning has been implied into different stages from elementary stage to higher educational stage across different disciplines from social science to mathematics, engineering, and medical.

But, still there are some concerns related with authentic learning. Firstly, using emerging technologies like VR/AR can increase the cognitive load as these contents contain multiple representations like symbol, audio, video, and animation. Course designers need to play an important role in designing the courses to minimize cognitive load/distraction for the learners so that students do not divert from the objectives the course. Secondly, we need to think whether these technologies are affordable by developing countries like India and Sri Lanka. If we are thinking for future development for the next generation, then we need to consider inclusive education. Developing countries must be involved in the creation of a new world. Low cost but effective technologies could be the solutions to provide real-life classroom environments in developing countries. The most important player is the teacher. We can provide the technologies in the classroom, but teachers need to play the important role. Therefore, professional development of the teachers is very important to implement the successful use of emerging technologies with authentic learning in the classroom.

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# Analysing Performance in Authentic Digital Scenarios

**David C. Gibson and Dirk Ifenthaler**

**Abstract** When components of authentic learning are enabled by technology and the event-level interactions of learners are recorded as a historical stream of items, a voluminous and varied data record of the performance in the scenario rapidly accumulates into a transcript. This transcript, the context in which it was created, and based on it, the purposes, intentions, and practical utilities of making interpretations and inferences about what someone knows and can do is key to analysing performance in authentic digital scenarios. However, an effective assessment system not only provides a signifier of what people know via a classification and token such as a grade or badge, but also provides evidence of actions, artefacts, and processes, how knowledge was formed over time, and how well the person is able to apply the knowledge in specific situations.

**Keywords** Performance assessment · Digital scenario · Authenticity · Real-world problem

## 1 Defining Authentic Scenarios and Digital Interactions

In order to set the stage for a discussion of recent analyses of performance in authentic digital scenarios, we define two terms: *authentic performance* and *digital interactions*. Authenticity is an important criterion for observing and analysing a digital performance, because the validity of observable evidence of knowledge (i.e. the acquisition, possession, and application of declarative as well as procedural knowledge) is provided by actions (e.g. making, doing, enacting, and communicating) situated in a particular context or scenario (e.g. collaborative problem-solving) and culture (e.g. a science or humanities) (Brown et al. 1989;

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Rosen 2015). Four recognized components of authenticity are real-world problems, inquiry learning activities, discourse in a community of learners, and student autonomy (Rule 2006) which are elaborated below.

When we refer to *digital interactions*, we are referring specifically to data inputs collected by an interactive computational application that either come directly from the learner or secondarily from aggregations of those inputs. A mouse click, tracked eye movement, and keyboard press are examples of direct event-level interactions, and a group of such actions, such as forming a word with keyboard presses or organizing screen resources into a priority order by dragging and dropping them onto an image, are examples of aggregated sets of actions (Ifenthaler and Widanapathirana 2014; Nasraoui 2006). When the components of authentic learning are enabled by technology and the event-level interactions of learners are recorded as a historical stream of items, a voluminous and varied data record of the performance in the scenario rapidly accumulates into a transcript (Berland et al. 2014; Romero and Ventura 2015).

This chapter addresses that transcript, the context in which it was created, and based on it, the purposes, intentions, and practical utilities of making interpretations and inferences about what someone knows and can do.

## 2 Criteria for Authentic Digital Scenarios

Building on the two definitions presented above, we propose criteria for authentic digital scenarios as those in which an activity is situated in a cultural practice (Young 1993).

- *Real-world* problems that engage learners in the work of professionals are also referred to as 'epistemic frames' (Shaffer 2006) which are knowledge community's ways of knowing, valuing, and expanding their body of knowledge. We might think of this criterion of authenticity as the 'social epistemology' of the scenario, which highlights the role of the community of practice (Bransford et al. 2000; Grotzer et al. 2015) in maintaining and recognizing creative innovations in a body of knowledge (Csikszentmihalyi 1996).
- *Inquiry* activities that provide practice with thinking skills and metacognition involve autonomy, exploration, and creative application of concepts during problem-solving (Caliskan 2012), leading to deeper learning via self-directed construction and increasing competence of one's mental models (Ifenthaler and Seel 2013).
- *Discourse* among a community of learners provides discipline-focused interactions and relatedness as a context for situated learning, practice, and assessment and supports the growth of expertise (Hickey and Zuiker 2012; Lave 1991).

- *Autonomy*, empowerment, and self-efficacy are enhanced through choice and control (Bandura 1997; Eseryel et al. 2014). Choice supports autonomy and, when combined with competence and relatedness, yields enhanced self-motivation and mental health, which are essential for positive decision-making and self-directed learning (Ryan and Deci 2000).
- *Unobtrusive measures* capture the direct and aggregated *digital interactions* in the performance without disturbing natural thought and action situated with the components (Clarke-Midura et al. 2010; Dummer and Ifenthaler 2005; Webb et al. 2013).
- *Timely observations* based on the measures, both automated and human (which implies feedback loop and possibility for user action), are made with a minimum of disturbance to the context, culture, and activity (Ifenthaler 2014; Ifenthaler and Widanapathirana 2014).

We combine these criteria and definitions into the concept of an *authentic digital performance space* designed with an educative purpose. The authentic digital performance space subsumes what others have called a *virtual performance assessment* when the purpose is focused on replacing less-authentic traditional testing (Clarke-Midura et al. 2012; Ifenthaler et al. 2014). Examples of other purposes of the generalized authentic digital performance space include research and development of:

- Knowledge maps of learners under a variety of conditions (Hanewald and Ifenthaler 2014; Ifenthaler 2010a; Ifenthaler and Pirnay-Dummer 2014),
- Challenges and issues of network analysis (Ifenthaler 2010b; Shaffer et al. 2009),
- Evolution of digital spaces enhanced by participatory teaching and learning methods (Gibson 2010),
- New psychometrics of digital performance spaces (Behrens et al. 2012; Eseryel et al. 2013; Gibson and Clarke-Midura 2015; Ifenthaler et al. 2012),
- Quality automated formative feedback in scalable online learning (Ifenthaler 2011; Webb and Gibson 2015),
- Understanding the social utility of the affordances such as space for collaboration (Rosen 2014, 2015).

Research is needed on the application of the criteria to levels of authenticity that result from variations in the criteria. For example, is it sufficient to have a near-real-world experience with a low level of choice? Is it effective to have high levels of discourse with low levels of inquiry? To what degrees do various levels of obtrusive measures impact one's performance? We will assume that there will be observable impacts of low levels or absence of any of the criteria (or corresponding high levels of interference with the criteria) on the authenticity of the scenario and someone's performance in the scenario (see Table 1).

**Table 1** Examples of impacts of authentic digital scenario criteria

| Criterion | When missing | When present |
|---|---|---|
| Real world | Irrelevance, distant or future need to know, simplicity, minimum cognitive load | Immediacy of need to know, complexity, maximum cognitive load |
| Inquiry | Received passive knowledge | Constructed active knowledge |
| Discourse | Individual misconceptions are not surfaced or challenged | Mental models are socially validated |
| Autonomy | Lack of freedom and control | Increased self-direction and motivation |
| Unobtrusive measures | Interrupted decontextualized performance | Natural application of knowledge-in-action |
| Timely observations | Feedback not available to improve performance | Micro-adjustments and incremental improvement |

## 3 Digital Interactions as Evidence of Authentic Performance

Evidence is interpretation of data to make a claim. What we are concerned with here is how digital interactions can be interpreted as evidence for the claim of authentic performance given the criteria outlined above. A foundational model for interpretation is given by evidence-centred design or ECD (Mislevy et al. 2006) in which a chain of reasoning flows from evidence collected at one level (e.g. atomistic events) to inferences and claims about the learner at another level (e.g. aggregations, comparisons, and interpretations). The inference can be remote from the evidence in both space and time, as when a post hoc analysis makes a claim or when someone reflects on what they learned from a past experience.

The path from events to inferences is defined and bounded by an ECD model of *a representative performance that has been validated by subject domain experts*. The model of performance then supports a chain of inference that leads from events to justified interpretations based on that evidence. The ECD modelling process includes domain analysis, domain modelling, constructing a virtual performance space with a conceptual assessment framework, and then implementing and delivering a prompt or virtual performance space that elicits authentic performance (Mislevy et al. 2006).

Before further considering interpretation and inference, note that a nearly complete performance can be replayed to some particular level of representational accuracy by replaying the transcript of the digital record. This is a unique affordance of an authentic digital performance that is generally less available in real-world performances, even when documented by video recording. Similar to a video recording of a real-world performance, a digital record is always taken from a particular perspective through a focusing lens that captures only the external portions of the events (e.g. not a complete picture of the mental models and representations of the actors) (Ifenthaler 2008). So partiality in interpretation and inference are ever-present. Human interpretation, consumption, and responsive action are therefore common objectives of analysis in both real and virtual situations. With replay, partiality, and human interpretation in mind, we are nevertheless concerned with codifying and automating as much as possible so that multiple levels of analysis can be extracted and entrained from the physical record and multiple interpretations can be supported by evidence.

Analyses of the performance transcript, even when automated and multileveled, are a mixture of *conditional and inferential interpretation* that can utilize several frames of reference while adding layers of interpreted evidence, insights concerning the complexity and additional dimensionality to our understanding of the performance and our ability to represent the performance in the light of our understandings. A conditional interpretation is one made with partial and incomplete knowledge (Pereira and Pollack 1991). For example, in natural language processing, the rules of how phrases fit together help determine the possible interpretations of parts of an utterance, but the complete meaning only becomes evidence as the rest of the context and the complete utterance becomes available (Indurkhya and Damerau 2010). We might think of the process as a drawing that we are watching take shape, where initial outlines of a sketch might be abandoned and new lines filled in with details at a later stage of the observation. Once complete information is available, or a 'stop' occurs in the observations, then a summative judgment or inferential interpretation represents the best we can do with the available information. We describe this process below as part of an assertion that *exploratory data mining is a necessary initial stage of research into a new digital performance space*.

## *3.1 Evidence-Centred Claims*

Claims about what someone knows and can do based on an assessment are supported by a chain of reasoning or argument leading from data to the claim, which is in turn supported by warrants (e.g. hypotheses or truth statements) and backing (e.g. historical data). A claim can face a counterargument supported by alternative hypotheses and rebuttal data (Mislevy et al. 2003).

Establishing validity entails making the warrant explicit, examining the network of beliefs and theories on which it relies, and testing its strength and credibility through various sources of backing. It requires determining conditions that weaken the warrant, exploring alternative explanations for good or poor performance, and feeding them back into the system to reduce inferential errors (Mislevy et al. 2003).

## *3.2 Designing a Claim*

The conceptual assessment framework has three core components: the student model, task model, and evidence model within and among which the time-sensitive relationships adhere (Mislevy et al. 2006). The measurement problem for authentic performance in a digital space is, by this theoretical framework, how to compare an actual to an expected performance (i.e. student model), how to take stock of the situation or prompt that evokes that performance (i.e. task model), and, from these sources of information, how to build a defensible inference from the evidence in a complex performance environment (i.e. evidence model).

Accordingly, the classification system of an assessment of a digital performance has to handle *patterns of simultaneous and sequential interactions* as well as a *hierarchy of relationships in a complex network* in order to make valid links to time-sensitive evidence rules within the conceptual assessment framework (Gibson and Jakl 2015).

## 4 Primary Challenges of Digital Performance Analysis

An effective assessment system not only provides a signifier of what people know via a classification and token such as a grade or badge, but also provides evidence of actions, artefacts, and processes, how knowledge was formed over time, and how well the person is able to apply the knowledge in specific situations (Baker 2007).

Over the last 25 years, the analysis of the learning-dependent construction and progression of knowledge has been discussed extensively (Johnson-Laird 1989). Still, reliable and valid assessment techniques for capturing changes in knowledge structure are still being developed (Baker et al. 2008). We note that knowledge is internal and its representations are internal (Ifenthaler 2010b). A direct assessment of these internal knowledge representations is therefore not possible, and different types of knowledge structure require different types of representations. The interrelationships between internal knowledge structure and external analysis artefacts can be described by distinguishing three zones—the object zone *W* as part of the world, the knowledge zone *K*, and the zone of internal knowledge representation *R* (Ifenthaler 2010b). In addition, performance analysis must rely on two functions: (1) $f_{in}$ as the function for the internal representation of the objects of the world (internalization) and (2) $f_{out}$ as the function for the external re-representation back to the world (externalization) (Ifenthaler 2010b). Neither class of functions ($f_{in}$, $f_{out}$) is directly observable. Accordingly, performance analysis requires a dual process of encoding (Galbraith 1999; Wygotski 1969). Within internal encoding, a mental model is constructed out of one's actual available world knowledge in order to create subjective plausibility (Ifenthaler and Seel 2013), i.e. a mental model is represented as an internal knowledge structure. The actual performance analysis occurs through communication of knowledge structure requiring the use of adequate sign and symbol systems but also a format of communication, which the performance analysis environment requires. Clearly, these complex cognitive processes result in a biased measurement of knowledge representation as researchers are currently not able to more precisely define the above-described functions of internalization and externalization. Finally, within digital environments the possibilities of authentic knowledge externalization and performance analysis are limited to a few sets of sign and symbol systems, namely graph-based and language-based approaches (Ifenthaler and Pirnay-Dummer 2014).

Inferring what someone knows and can do based on digital interactions thus depends on the affordances of the game or other e-learning experience *as a performance space for assessment* (Mayrath et al. 2012). Combining *digital performance* with *performance assessment*, this concept of a gamified e-learning experience includes all types of performance in which computer technologies have taken on a primary rather than an auxiliary role in the content, techniques, aesthetics or the delivery of someone's expression, and where the digital record is used as evidence of learning. The concept implies new challenges for psychometrics due to the increased complexity of the digital record (Ifenthaler et al. 2014). At the atomistic level, performance data issues include time and event segmentation, cyclic dynamics, multicausality, intersectionality, and nonlinearity. At the summary level, the key challenge is model building and providing authentic real-time feedback (Gibson and Jakl 2015).

## 5 Conclusion

Assessing simple problem-solving is straightforward since there is usually a single correct answer to such problems (Funke 2012). However, analysing performance in authentic digital scenarios is more challenging because authentic real-world problems do not have standard correct answers and often require expert teams interacting over a longer period of time to develop and perform a solution (Eseryel et al. 2013). Accordingly, a large record of data about the context of the authentic digital scenario and the actual performance of an individual or a team needs to be stored and analysed in real time. This requires intelligent adaptive algorithms of learning analytics in order to enable meaningful analysis as well as personalized and adaptive feedback to the learner.

Such algorithms for personalization have been developed; however, only a few have been implemented in educational settings (Drachsler et al. 2008): 1. Neighbour-based algorithms recommend similar learning materials, pathways, or tasks based on similar data generated by other learners. 2. Demographics algorithms match learners with similar attributes and personalize the learning environment based on preferences of comparable learners. 3. Bayesian classifier algorithms identify patterns of learners using training sets and predict the required learning materials and pathways. In addition, these algorithms have several shortcomings. First, they are not sensitive to semantic characteristics of the learner and the learning environment. Second, they lack validity in fully automated learning environments. Third, empirical evidence focussing on benefits for learning is scarce (Ifenthaler and Widanapathirana 2014). Forth, the acceptance of fully automated systems among learners is limited.

To conclude, analysis of performance in authentic digital scenarios could benefit from semi-automated implementation of personalized learning environments at scale.

Such an approach could include machine learning algorithms (MLA) that are continuously shaped by human actions (e.g. teachers, the learners themselves, experts, and others). The ratio between MLA and the human for personalizing the learning environment depends on a) the available data in the system (e.g. learner characteristics, prior knowledge, learning patterns recognized), the subject domain as well as the task complexity and competence or performance level to be achieved. Accordingly, MLA will assist intelligent digital scenarios in making decisions for personalized learning environments and teachers will validate recommendations by MLA.

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# Cultivating Creativity by Scaling up Maker Education in K-12 Schools

**Ronghuai Huang and Xiaolin Liu**

**Abstract** Maker Education is one of the effective complements for traditional classroom education, which bears the potential of boosting knowledge learning, practical ability and creativity cultivation. Upon a brief retrospect of the history of China's" Maker Movement" and an exploration of innovation ability and intelligence development, this thesis summarizes the traits of students' cognitive development and scientific literacy during each stage of K-12 education and probes into the development approach of Maker Education in K-12 schools. The author believes that Maker Education should resort to different strategies according to students' cognitive development and scientific literacy, including "learning by gaming," "learning by doing" and "learning by working" based on real-life contexts in a piecewise manner.

**Keywords** Maker Education · Maker Space · Innovative ability · K-12 education · Development path

## 1 Introduction

Innovation is the well and inexhaustible impetus of human civilization and progress. The cultivating of innovative talents on state-level has always been the top priority in education for countries around the world. Among world education systems, some have established specialized schools for the training of innovative ability, such as SHH (Super Science High School, a key science senior high school) in Japan; others have founded project institutions, such as PLTW in the USA and trans-regional special field research project in Germany (SFB/TR) (Li et al. 2016).

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Regardless of the form, both specialized schools and project institutions aim at building students' innovative ability which is highly valued by the Chinese government. On November 19, 2015, Liu Yandong, vice-premier of the state council, stressed on the Second National Conference On ICT In Education that "it is required that we should proactively explore the application of information technology in Start-Up University+, Maker Education and the development of micro-classrooms, improve students' information literacy, entrepreneurship and innovative ability, and cultivate a healthy and positive cyber culture in a way that facilitates students' comprehensive development." At present, Maker Education is a key territory for IT application in education vigorously advocated by the Chinese government, while the development of it is closely related to the cultivation of students' entrepreneurship and innovative ability.

Makers are to do and create, which means ones identify key issues and needs in reality to find solutions by action and practice, conveying the positive attitude toward life. Maker Education reflects a rational thinking which forms an interactive relation of coexistence and open-mindedness between learners. Authentic education addresses learners' psychological and neurological needs and embraces diversity within the human species more meaningfully by providing personal development, which is highly correlated with Maker Education (Watagodakumbura 2013).

By briefly reviewing the development process of China's Maker Movement, this essay discusses the development of innovative ability and intelligence, summaries the traits of student's cognitive study and scientific literacy during all grades of K-12 education and probes into the development approach of Maker Education in K-12 schools on this basis.

## 2 Maker and Maker Culture

For the past decade, the maker movement—an interest in working with one's hands in interdisciplinary environments that incorporate various tools and technologies—has been on the rise. And it becomes a cultural phenomenon, deeply rooted set of values in the makers' worldview. In recent years, educators, administrators, parents and policymakers have expressed a heightened interest in maker-centered learning, the incorporation of the practices of the maker movement into education.

### *2.1 The Past and Present of Maker*

The wide spreading of the word "Maker" should be attributed to Chris Anderson, ex-editor for Wired, name for an American magazine. Makers are a group of people with technical know-hows and the awareness of innovation and communication, and they are able to convert originality into reality with certain technical support (Anderson 2012). Although "Maker" is only a recent terminology commonly recognized, there is no lock of Maker and creative spirit at all times and in all over the world. The Chinese nation boasts rich creativity, and the creative spirit of Chinese people has been incarnated by "the four great invention" of ancient China and the agriculture technological reformation during the early stage of the founding of P.R.C. In ancient times, Makers created the compass, gunpowder, papermaking technology and typography, driving human civilization and gaining a fundamental foothold in world science and technology development. During the early years of the establishment of New China, the Party Central Committee and Comrade Mao Zedong proposed to strive for the basic completion of China's agricultural mechanization within around one decade in 1959 against the backdrop of the backwardness of agricultural production. Highly responded by the party people, this advocate has brought about the climax of agriculture mechanization and the movement of technological revolution. "Makers" in the New China devised the rice harvester that boosts the rice harvesting efficiency by leaps and bounds and saves manpower. In addition, more and more radio and model airplane amateurs founded clubs where they designed various practical works and created their own periodicals such as radio, model airplane, etc., for the communicating and sharing of ideas and design principle.

Currently, "Internet+" has ignited the climax of innovation and entrepreneurship and the era of Internet endows "Makers" new way of thinking and creative mode. They have contributed to an array communicated and shared by Maker Fair and Maker Games held by Maker alliance.

## *2.2 Maker Culture*

Maker Culture is a subculture derived from DIY culture. It is mainly reflected in the creation of new objects or the remedying of the deficiency of existing items utilizing electronic device, robot, 3D printing technology, CNC digital control tools and even more traditional metal and wood processing techniques and industrial arts (Wikipedia 2013). It emphasizes participatory learning that is non-formal, web based, peer assisting, stimulated by interest and self-realizing and that encourages innovative application for technology. Makers are adventurous in the crossover of traditional metal processing, calligraphy, video production and computer programming, etc. In this sense, they represent an open-minded, crossover, trial-and-error manner of learning and fast iterative culture. The interaction and knowledge sharing in Maker community relies on database formed by social media tools, information sharing and social channels (such as Maker Space) for the sake of originality sharing. Prof. Li Zhengfeng Li (2015), from Tsinghua University, assumes that the Maker Movement carries four culture genes, namely Hacker Culture stressing sharing and the combating of technical problems, DIY culture converting ideas into reality and crossover cooperation stressing critical design and creativity.

Maker Culture has attracted the interest of educators, who expect to provide students with certain innovative and more attractive learning mode through Maker Education. By connecting knowledge learning and students' real life, it intends to arouse students' interest and motive for learning. Maker alliances are now being established by many provinces in China that offer a sequence of support for primary and middle schools in order to promote the development of Maker Education. What should be considered by them is how to provide Maker resources for teachers and students on a broader level, including Maker design cases, tools, materials and professional training for Maker teachers, etc. It is worth noting that there have been quite a number of online Maker resources sharing activities, research and study activities for Maker teachers initiated by the civil society. Looking into the future, more social and corporate resources would be integrated to accelerate the development of Maker Education in coordination.

## 3 Intelligence Development and the Value of Maker Education

Maker Education encourages collaboration, invention and radical participation with a single goal: to create new things, which contributes to the creative and practical intelligence. Based on current educational situation, Maker Education is illuminated to develop students' successful intelligence.

### *3.1 Successful Intelligence: Analytical Intelligence, Creative Intelligence and Practical Intelligence*

The word "Intelligence" is derived from Latin verb "Intelligere" referring to the understanding and perception for things. The definition about it has not yet been universally recognized. Some typical ones include: "Intelligence is a kind of normal mental ability which covers the ability of reasoning, planning, problem-solving, abstract thinking and the capacity of understanding complex concepts, fast learning and experience-based learning. It is not only a narrow academic or test skill required by book leaning, but also an extensive and profound ability of perceiving and comprehending the world around" (Gottfredson 1997), announced by 52 researchers under the title of The Main Science about Intelligence on The Wall Street Journal in 1994; "Differences are found between individuals in understanding complex concepts, adapting to the environment effectively, learning through experience, conducting various forms of reasoning and overcoming difficulties through thinking, etc., which can be remarkable but not invariable. The intelligence performance of an individual might change in different occasions and contexts, and the evaluation criteria of intelligence can be different"(Neisser et al. 1996),

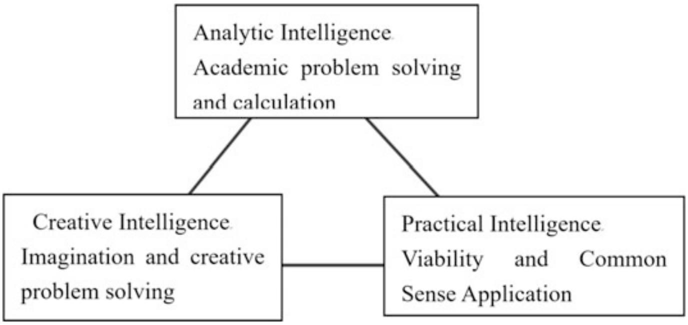


**Fig. 1** Triarchic theory of successful intelligence proposed by Sternberg

considered by The Board of Scientific Affairs of the American Psychological Association in its research report Intelligence: Knowns and Unknowns in 1995.

Despite different understanding of intelligence in different cultures and contexts, there are identical elements on intelligence level that would lead to the success of one person. (Sternberg 1997; Sternberg 2005) believes that successful human intelligence is an intelligence integration composed of interconnected triarchic relationships, with different length of each side leading to intelligence differences between individuals; the tripartite-structure of intelligence is composed of analytic intelligence, creative intelligence and practical intelligence, as shown in Fig. 1.

- Analytic intelligence is also called componential intelligence, referring to the ability of recognizing, solving and calculating academic problems. It plays a vital role on problem recognizing and solving. Examinations in most school education are designed for the evaluation of analytic intelligence.
- Creative intelligence is also called experiential intelligence, referring to the ability of solving new problems with existing experience and innovative ability integrated from different ideas. People with higher creative intelligence are able to adapt to new environment and solving new problems better than those with lower creative intelligence. After solving certain problems for multiple times, they can activate automatic problem-solving program to save their mental resources.
- Practical intelligence is also called contextual intelligence, referring to the ability of solving real-life problems using the acquired knowledge and experience. It is mainly reflected in viability and the application of common sense, which people should adjust or change according to specific cultural and historic contexts. The effectiveness of whether individuals can adapt to their living environment that need to satisfy daily demands reflects the levels of their practical intelligence.

The aforementioned analytic, creative and practical intelligence form the core of the exposition on intelligence of Sternberg, who indicates that prominent performance on a single aspect of intelligence cannot guarantee the success of an individual, whereas a successful person has to perform well on analytic, creative and practical intelligence all at the same time. This essay believes the triarchic theory of successful intelligence proposed by Sternberg can better explain and support the development of Maker Education.

## 3.2 Maker Education and Successful Intelligence

Reflecting upon the current education and teaching practice from the perspective of Sternberg's triarchic theory of successful intelligence, it is obvious that the type of intelligence being stressed and cultivated in school education is mainly analytic intelligence, while creative and practical intelligence has not yet attached to enough attention. The operational process of analytic intelligence can be divided into five steps: recognizing and identifying the problem, forming problem-solving strategy, selecting appropriate resources, supervising the problem-solving process and evaluating the problem-solving strategy. The conception of analytic intelligence is highly correlated to intelligence-based skills during the process of analysis, comparison, evaluation, explanation, decision-making and criticizing, and it is typically characterized by expressiveness, logics, organization and equilibrium during problem-solving.

Creative ability represents the highest form of intelligence, which transcends simple knowledge retrospect and ends up in knowledge creating. Creative intelligence is featured by three characteristics: ① Generating new ideas. Students in Maker Space all have a dream that actually contain a fundamental idea. ② Defining new problems which are neither posed listed in the book nor prescribed by the teacher but found by students out of their experiences instead. ③ Ability to promote good ideas. In fact, those tiny works created by Makers are their way of promoting and expressing ideas, a way that is concrete and visual. The conception of creative intelligence requires innovation, flexibility, high self-efficiency, perseverance, tolerance of fuzziness and unconventional thinking during the process of generating, designing, inventing imagining and proposed hypothesis. It is typically featured by the expressiveness, novelty, attractiveness and task suitability.

For practical intelligence, environmental suitability is needed to apply knowledge to similar problems in real-life situations. The conception of practical intelligence is associated with problem-solving through the correct application of technology and tools during technology and knowledge application, task implementation and the deployment of environmental and contextual problems. It is typically featured by the compatibility of the proposed ideas and space-time condition, human and material resources.

From the perspective of real-life school education, the majority of teaching activities are conducted according to disciplinary classifications such as mathematics, language and literature and English, etc., which can even amount to more than ten in senior high school. Subject teaching, to some extent, leads to knowledge isolation artificially. Maker Education is one of the effective complements for traditional subject education, especially for the development of students' creative and practical intelligence, as shown in Fig. 2. What should be noted is that most Maker Space and works created by students all end up in the cultivation of analytic

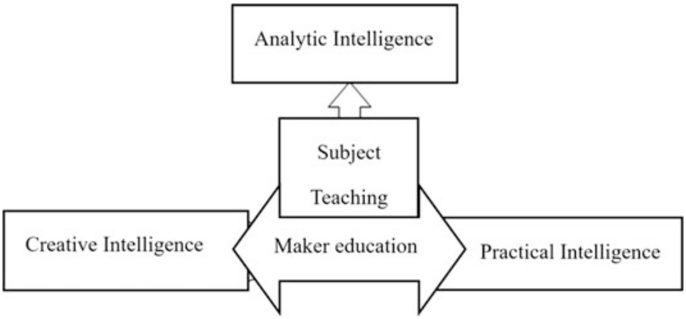


**Fig. 2** Maker education is one of the effective complements for subject teaching

and practical intelligence, whereas creative intelligence still holds boundless room for improvement both at home and abroad. It is required to conduct in-depth research on the following questions: what is the relation between Maker Education and other subjects? How should Maker Education be operated, in the form of interest groups or school-based curriculum? Should it be associated with other subjects? Whatever the form, the process of Maker Education and its strategies should cater to the features of students' cognitive development and scientific literacy throughout K-12 education.

# 4 Learning Mode Based on Students' Cognitive Development and Scientific Literacy

The purpose of Maker Education is to facilitate the development of students' intelligence in an all-around way, especially creative and practical intelligence, and to improve students' scientific literacy. The regularity in students' process of development results in different teaching modes for Maker Education among different phases of studying. School-based Maker Education should consider students' demands for cognitive development, scientific literacy and e-learning ability in each phase of K-12 education.

## *4.1 The Characteristics of the Development of Students' Cognition and Scientific Literacy*

A research in cognitive development psychology has shown that the cognition of elementary school students focuses on concrete operation which transits to formal operation in higher grades, learning interests deviate in the third grade (Zhu and Zhu 2003). As a result, elementary students' way of thinking starts from concrete thinking and gradually moves to abstract thinking that only enables simple problem-solving based on direct observation (Zhu 2008). They tend to be more interested in the process and external activities of learning because of their attention deficit. With the increase of grades, their ability of problem-solving also improves gradually (Chall 1996). In terms of scientific literacy, they begin learning and comprehending the basic knowledge related to science. With the natural interest and curiosity in science, they are keen on exploring specific objects. For e-learning ability, they feature low digital literacy but higher demands for digital resources with videos, images and animation, etc. Due to their incompetency in the processing and application of digital text resources and deficiency in self-control under the information environment, schools, parents and the society should pay much more attention to them.

The abstract logical thinking of middle school students is built progressively and their problem-solving ability based on information processing grades into stability. They are able to learn and grasp the core concepts of science and describe, explain and probe into the world around with scientific knowledge. Their social responsibility also takes initial shape at this stage. With the noticeable progress in digital learning ability and basic ability in digital information processing, they will be able to engage in complicated information processing activities, despite relatively low self-control ability under the e-information environment.

In terms of cognitive development, the abstract logical thinking ability of high school students grows mature and their occupational preference is formed. It is a critical stage to cultivate students' critical and practical thinking ability. For scientific literacy, they are capable of conducting scientific research and filing proposals for the solution of engineering problems with the learning of natural and social sciences including physics, chemistry and biology, etc., and the preliminary and comprehensive understanding of the external world. In addition, the e-learning ability of high school students grows stronger that enables them to process and express information with the aid of multimedia resources flexibly. They desire for socialized communication and personalized development regardless of low self-control ability under the e-information environment as ever.

## *4.2 Learning Mode Based on the Characteristics of Students' Cognitive Development and Scientific Literacy*

The characteristics of the cognitive development and scientific literacy for students in K-12 education generate the differences of learning and teaching modes, which further determines different development paths for school-based Maker Education in different learning stages, as illustrated in Fig. 3. In brief, Maker Education should center on "learning by gaming" in elementary school stage, "learning by doing" in middle school stages and "learning by Working" facing real-life problems in high school stages.

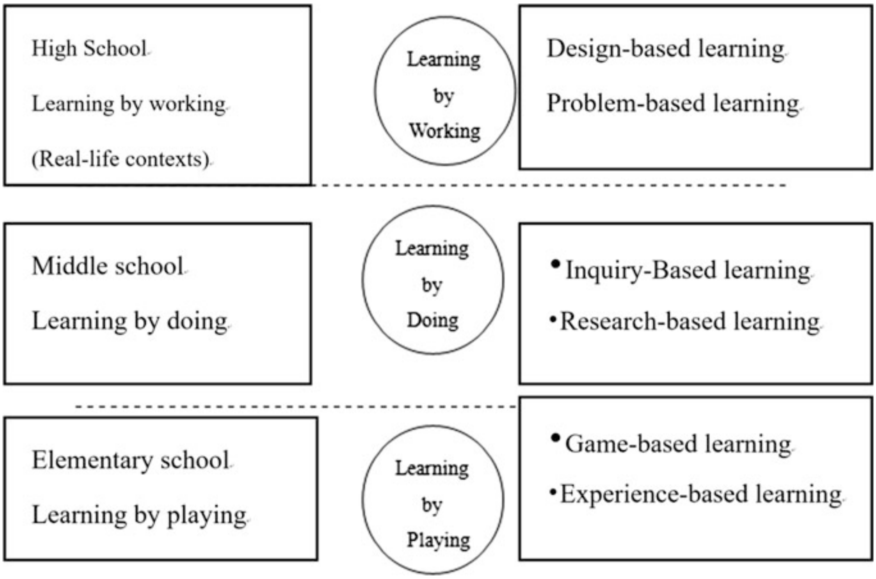


**Fig. 3** Learning mode based on the characteristics of students' cognitive development and scientific literacy

The main idea of "learning by gaming" is that learning takes place spontaneously in the process of playing where pupils not only acquire basic knowledge, skills and literacy, but also begin to build a preliminary perception and understanding toward the social norms (Whitebread et al. 2009). Vygotsky deems that gaming is vitally important to the development of children, for they are able to practice self-control, acquire knowledge and develop social behaviors of cooperation while gaming (Vygotsky 1978). For children, "learning" and "gaming" are the two activities generated naturally in their daily lives. The integration of "gaming" and "learning" is mobilized by them as a matter of course out of their comprehension of "gaming" and "learning"(Docket 1999). Therefore, Maker Education should prioritize "learning by playing" in the learning modes of pupils.

"Learning by doing" emphasizes that education should "be oriented to social life and the application the individual lives of the kids" so that learners can think and solve problems or similar problems in different contexts with existing knowledge (Dewey 1901). The idea of it consists of two significant prototyping activities: handicraft activities and scientific inquiry activities. The former is devoted to explicit, hands-on, concrete and emotional processes and explicit and fashioned results such as handicrafts, paintings, models and propaganda materials, while the latter stresses the inquiry of the way of thinking that is implicit, reflective and rational, as well as conceptual results such as new perceptions, opinions and perceptions yielded during the activities (Zhang and Sun 2006). It is divided into four cycles of activities, namely concrete practice, reflective observation, thinking and verification (Kolb 1984). A concise illustration of this mode of learning is experiencing the process of inquiry, constructing fundamental knowledge and developing thinking and research ability via observation, questioning, presumption, hands-on experiments, recording, expression and communication, etc. (Lai and Ding, 2005).

Originally, "learning by working" indicates learning occurring in real-life work places. Students in high schools grow mature in their way of thinking and form a preliminary occupational preference. In consequence, previous "book-centered" learning fails to fully satisfy students' demands for development. The learning mode of students at this stage, therefore, should focus on the learning based on real-life problems and contexts, which is known as "learning by working." During this phase, particular efforts should be made to the correlation between the learning contents, which a moderate opening up, and the world and the society beyond.

## *4.3 The Development Path for Maker Education in China's K-12 School*

Maker Education for K-12 education schools is carried by: ① Maker interest groups for design-based learning, which stresses in-depth experience in the process of creation; ② Project-based learning through courses of IT, comprehensive practice or other school-based curriculum, which features the experience of creation methods; ③ Experience-based learning through associated subject modules, which underlines the connection between interdisciplinary knowledge, as shown Fig. 4.

Regardless of the formats based either on interest groups, IT and comprehensive practice courses, or on associated subject modules, the transform from conventional "academic problems" into "practical problems" is required for Maker Education. The

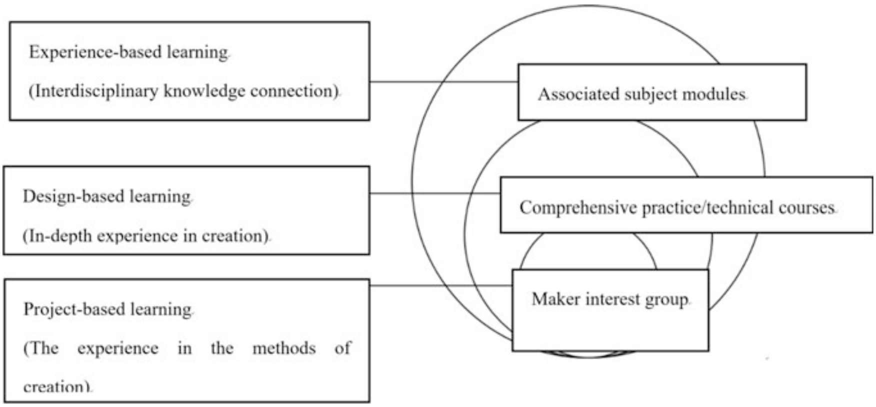


**Fig. 4** Carrier formats of maker education

**Table 1** Differences between "Academic" and "Practical" problems

| "Academic problems" are more inclined to | "Practical problems" are more inclined to |
|---|---|
| Be planned by others | Require problem identification and planning |
| Be well defined | Be ill-defined |
| Be complete | Require clue searching |
| Have only one correct answer | Have multiple answers acceptable |
| Have single route to the correct answer | Have multiple routes to the answers |
| Be isolated of real-life experience | Be embedded in or require daily life experience |
| Lead to light or little interest in learning | Lead to strong interest and devotion in learning |

differences between "academic" and "practical" problems are listed in Table 1. The former is more inclined to well-formed problems with the only right answer prescribed by teachers or books, which are in isolation of the practical experience of students and are far from attractive to them; however, the latter is usually a group of problems that is ill-structured, complicated and is only to be solved with hidden clues. They intend to be identified and designed by learners themselves with often more than one solution. Apart from that, "practical problems" have been embedded in or in need of daily life experience so that students' desire for learning is strong and they are able to devote themselves into learning activities.

## 5 Conclusion

With a brief review on the history of the development of Maker Education in China, the inquiry of intelligence and intelligence development, a summary of the traits of students' cognitive study and scientific literacy during all grades of K-12 education and the study on the development approach of Maker Education in K-12 education, this thesis arrives in the following contentions:

First, Maker Education is one of the effective complements for traditional classroom teaching, which has the potential of facilitating knowledge learning and the cultivation of practical ability and creativity. The construction of Maker Space should be coordinated with school environment, curriculum, teaching reform and cultural construction.

Second, Maker Education should employ different strategies for students in elementary school, middle school and high school according to their cognitive development and scientific literacy. Its piecewise solution would be from "learning by gaming", "learning by doing" and "learning by working" based on real-life contexts.

Third, Maker Education is realized through independent interest groups, courses of comprehensive practice and IT or associated subject modules, which contribute to the in-depth experience and methods of creation as well as interdisciplinary knowledge connection, respectively.

Fourth, the advance of regional Maker Education asks for strong and powerful regional service system for Makers, including the access of equipment, product information, experience exchanges among teachers, the sharing of design and organizing methods and the incentive mechanisms for design and originality, etc. Regional alliance is the typical form of service support system.

Fifth, Maker Education should fully utilize the Internet platform and technology to break down the inherent barriers existing in traditional classrooms, schools and regions so that both teachers and students can contribute to and share their wisdoms and achievements in an joint effort for the cultivation of learners' creative ability.

**Acknowledgements** If you wish to acknowledge persons who contributed or sponsoring agencies, do so here in this optional section.

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## Author Biographies

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# Part II
# Development and Implementation of Authentic Learning

# Interactive Electronic Book for Authentic Learning

**Po-Sheng Chiu, Yen-Ning Su, Yueh-Min Huang, Ying-Hung Pu, Pei-Yu Cheng, I-Ching Chao and Yong-Ming Huang**

**Abstract** Classroom is a professional field of teaching and learning. After going to classrooms, teachers have to face curriculums, each student, and other dimensions and needs. Besides careful management, adjustment of teaching strategies should be considered according to individual difference, and this can achieve win–win relationship between teachers and students, and create a friendly learning environment. Thus, satisfying learners' different needs for learning is an important issue in the education domain. Owing to the advent of e-book, it provides educators a new way to conveniently assess every student's learning status in diverse dimensions. For example, one potential advantage is the greater flexibility and accessibility of e-books over paper books, and the characteristics of e-books could provide authentic contexts and activities. Therefore, e-books have the potential capacity to achieve authentic learning instead of traditional textbooks. With the experiences in the development of e-books and educational technologies, we have seen an

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emerging trend in the application of e-books to authentic learning. Therefore, this chapter aims to investigate the suitability of different kinds of e-books for the educational environments, and the potential benefits of integrating e-book in authentic learning. It is hoped to suggest readers a further research blueprint for this topic.

**Keywords** Authentic learning · E-Books · Textbooks

## 1 Introduction

Classroom is a professional field of teaching and learning. After going to classrooms, teachers have to face curriculums, each student and other dimensions and needs (Smolkowski and Gunn 2012). Besides careful management, adjustment of teaching strategies should be considered according to individual difference, and this can achieve win–win relationship between teachers and students, and create a friendly learning environment (Huang et al. 2014). Thus, satisfying learners' different needs for learning is an important issue in the education domain.

Authentic learning characterizes the type of leaning which students learn in their natural environment with the real-world issues and complex problems (Herrington and Oliver 2000). Authentic learning typically focuses on real-world, complex problems and their solutions and use role-playing exercises, problem-based activities, case studies, and participation in virtual communities of practice. On the other hand, authentic learning takes a constructivist approach (Honebein et al. 1993). Teachers provide opportunities for students to construct their own knowledge through engaging in problem solving, higher-order thinking, and reflections in real-world contexts. This knowledge construction is heavily influenced by the student's prior knowledge and experiences. It allows students to draw connections on their own. Some scholars considered (Herrington 2006; Huang and Chiu 2015) that information technology supporting authentic learning should providing authentic contexts that reflect the way the knowledge will be used in real life. Fortunately, the characteristics of e-books could provide authentic contexts and activities (Huang and Chiu 2015). Therefore, e-books have the potential capacity to achieve authentic learning instead of traditional textbooks.

Nowadays, rapidly evolving technology, especially computer technology, has an important role in our lives. In the recent decades, with rapid advancement of multimedia, network, and mobile technology, development of digital learning is flourishing. Almost all of subject disciplines involve computers and digital technology, as well as learning and teaching activities (Chiu et al. 2016). Could we leverage ICT technology positively to the authentic learning? The emergence of e-book seems unveiling this possibility. However, how to capitalize e-book to support authentic learning is inevitably become a big issue. Nowadays, the e-book reader equipped a high-resolution color display has become the most popular personal digital devices (Huang et al. 2012). It is anticipated that e-books may substitute paper books in the future. One potential advantage is the greater flexibility and accessibility of e-books over paper books (Ref.); others include increased visual appeal of e-books due to features such as still and moving graphics, and video clips, as well as the potential to add supportive materials such as audio collections, links to activities, and Websites. It is important to evaluate electronic texts as learning tools before recommending or requiring their use as a substitute for print textbooks (Bierman et al. 2010). Early in the literature about e-book, it was discussed the advantages of e-book in comparison with paper books (Korat 2010; Korat and Shamir 2007, 2008). Furthermore, e-books have more advantages than paper books, such as less storage room, lower cost of publication, and quicker search (Huang et al. 2012). In a research report on comparing between e-books and paper books, it was indicated that one potential advantage is the greater flexibility and accessibility of e-books over paper books (Huang et al. 2012). Education is a field where the e-book might well be fruitfully employed.

A well-suited user interface (UI) and functional design for e-books is a critical step for authentic learning (Yuill et al. 2009). Some researchers examined a series of new user interface paradigms with a sociocultural approach that can work to mediate the collaborative learning among children (Kerawalla et al. 2008; Yuill et al. 2009). The results suggested that the additional features are still needed to improve the content of the collaborative conversations that support joint understanding and individual comprehension development. In addition, human-to-computer interactions are fundamentally social responses, and they suggested that enhancing the interactivity of an e-learning environment can stimulate the presence of social actors, which can promote a child's learning experience and increase their motivation (Tung and Deng 2006). The students' engagement in online literature discussions promoted socially constructed learning, and that the students' skillful and in-depth communications reflected their prior experiences in both real and virtual environments. Huang and Huang (2015) revealed that social interactivity and scaffolding instruction are both crucial for learning, and sharing e-book reading and scaffolding procedure enhance the word learning of children. UI designs and functionality seem to influence children's learning process, and even affect their learning performance (Bierman et al. 2010). Some researchers thus suggested that the e-book UI and functionality should be developed to better meet the specific users' learning needs (Lam et al. 2009). For the realization of a successful and effective authentic learning, some requirements should be taken into consideration. As a result of studies, it is observed that interactive e-book environments meet the requirements of authentic learning. Looking at opportunities offered by interactive e-book, it provides the necessary conditions for authentic learning. Therefore, this chapter aims to investigate the suitability of interactive e-book for the educational scenario, and the potential benefits of integrating e-textbooks in authentic learning. It is hoped to suggest readers a further research blueprint for this topic.

## 2 E-Books and Authentic Learning

Among studies conducted on application of e-books in teaching, Bierman et al. (2010) adopt online questionnaire and interview methods to analyze the experiences of 11 professors (theories and applied sciences) with use of e-books in teaching and research. The outcome showed that users think much more can be achieved in application of e-books and hope that more needs with regard to application in the academic sector could be taken into account in future development of e-book functions and interfaces. Meanwhile, students also have similar responses. Lam et al. (2009) study the opinions of 12 university students about use of e-books in learning. The result indicates that the students believe e-books should be able to help learning. However, they expect more than the current performance of e-books and reading devices. In other words, e-books still have many defects that need improvement. Overall, both teachers and students are affirmative about the future development of application of e-books in teaching, but there are still a large number of bottlenecks to overcome.

In line with the expectations of teachers and students toward application of e-books in teaching, it may be possible to find the starting point of the direction of further e-book development by making assessments from the angles of learning scenarios and strategies. In recent years, for example, Western countries have been making active efforts to build authentic learning scenarios. Curricular activities have been designed to allow students to simulate real scenarios through role playing, special topic learning, case studies, participation in community activities and creation of works. At the same time, current social issues are also integrated to construct authentic learning environments to make classroom teaching more meaningful (Herrington 2006). More importantly, students can develop problem-solving abilities through open participation, initiation of ideas, expression of opinions, self-reflection, and self-learning, and this is the most effective way of learning able to trigger students' learning motivation (Herrington and Oliver 2000).

The main purpose of authentic learning theories is to enable students to apply knowledge and skills they have learned to solve problems encountered in reality (Herrington 2006), meaning that knowledge and issues in real life are integrated to train students to solve problems. In particular, the authentic learning factors proposed by Herrington and Oliver (2000) are the most representative. They include (1) provision of authentic scenarios able to reflect application of knowledge in real life; (2) provision of authentic activities; (3) provision of learning opportunities with specialists giving demonstrations; (4) provision of a variety of roles and angles; (5) provision of cooperative learning to build knowledge; (6) promotion of self-reflection to develop abstract concepts; (7) encouragement of expression of ideas to turn tacit knowledge into explicit knowledge; (8) teachers providing scaffoldings and guidance at crucial moments; and (9) evaluation of authenticity of learning in assignments. As the development of application of e-books in teaching is in full swing, exploring the use of e-books from the aspects of learning scenarios and strategies should have its value. Nevertheless, development of e-book software and hardware is still in an early stage. Plus, e-books have the characteristic of combining traditional reading and technological applications. Therefore, based on the abovementioned studies on e-books, the functions and application of scenarios of e-books require rethinking. For this reason, clarification of how e-books should be applied in authentic learning scenarios with examples of related practices also taken into consideration is an important task.

## 3 Case Studies

In this section, three cases are analyzed to unveil current use of e-books in authentic learning. The objective is to examine the interactiveness and sensing technology of e-books to find out the effect of use of e-books in authentic learning. Case 1: In a reading environment, video and pressure sensors are applied in e-book reading to understand the reading behavior of learners throughout the reading process, and the results are given to teachers for reference in classroom observation. Case 2: In language learning scenarios, the scaffolding theory is adopted as the basis to design a vocabulary learning game for an e-book, while a set of sensing techniques is also integrated to try to increase students' vocabulary learning motivation and results. Case 3: Brainwave analysis is applied to provide an appropriate feedback mechanism in the self-test system to help learners adjust their moods as well as to understand their mood changes in order to provide assistance for learners and teachers. The details are as follows:

### *3.1 Empowering Classroom Observation with E-Book Learning System*

Compiled from two papers published in two journals, *Educational Technology Research & Development* and *Interacting with Computers*, this case study is on elementary school students. Tablet computers using Microsoft Windows operating systems are used to conduct teaching with e-books, while touch screens and Web cameras are also provided for sensing.

The author of the paper published in *Educational technology Research & Development* uses an e-book system that complies with the needs in elementary school teaching. The application of the e-book is intended to develop e-textbooks. In this study, besides development of e-books suitable for elementary school teaching, observation of students' "reading behavior" is the main objective. In the meantime, the author of the paper published in *Interacting with Computers* takes a further step and includes also students' "level of concentration" to be a target of observation throughout the reading process. In addition to touch screens, web cameras are also applied in this study as the sensing equipment in order to construct an environment that allows recording of students' "level of concentration" and "reading behavior." The details are as follows:

Reading is a complicated cognitive process. If teachers can understand students' reading conditions in this process, they will be able to provide reading guidance suitable for each student. However, in conventional classroom environments, provision of such guidance is limited by the number of students in a class and the teacher's workload tolerance. In general, when a teacher spends too much time and energy on teaching or is too inexperienced to observe students, students will not be able to get the teacher's assistance when they encounter difficulties in reading. Consequently, the result of reading teaching will not be as expected. To solve this problem, e-books and sensing techniques are adopted in this case study to help teachers observe students' reading processes (Liang 2013).

Initially, tablet computer touch screens are used to analyze the reading speed and reading behavior. When a student touches the screen and rolls the page to read an e-book, the number of words read and reading speed per minute can be calculated according to the movement of the student's finger. Because reading speed can reflect the student's reading behavior, the student's reading behavior can be detected based on the reading speed detected and this allows the teacher to understand the student's reading condition and provide individualized guidance at the right time. The relations between reading speed and reading behavior are as shown in Table 1:

**Table 1** Summary of reading rates and reading behaviors (Liang 2013)

| Reading status | Reading rate (wpm) | Reading behavior |
|---|---|---|
| On-reading | 0–1,000 | |
| Slowing | <50 | Excessively slow<br>Inefficient reading<br>Disfluent<br>Labored<br>Inexpressive<br>Unenthusiastic rendering |
| Memorizing | 50–100 | Sustained attention<br>In-depth reading<br>Oral reading<br>Concentrated reading<br>Annotation (highlight) |
| Learning | 100–200 | |
| Rauding | 200–400 | Silent reading<br>Keyword spotting<br>One-time reading<br>Reading selectively<br>Browsing and scanning<br>Nonlinear reading |
| Skimming | 400–700 | |
| Scanning | 700–1,000 | |
| Off-reading | ≧1,000 | |
| Flipping | ≧1,000 | Flip pages<br>Glance and glimpse text |

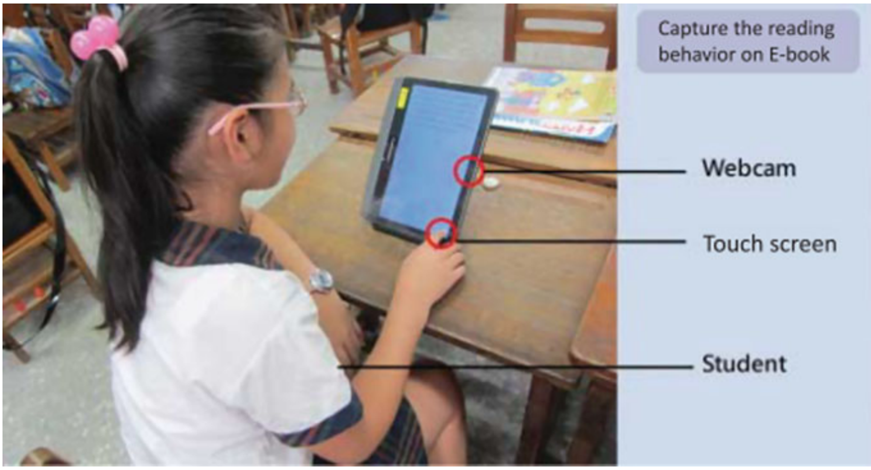


**Fig. 1** Schematic showing a student looking at the screen (Huang et al. 2014)

The web camera keeps track of whether the eyes of a student are fixed on the screen to assess the "level of concentration." When a student is reading normally, the eyes are focused on the screen of the tablet computer and this can be detected by the web camera. On the contrary, if the reading behavior is not normal, the eyes are not focused on the screen. The concentration level detection with the web camera is as shown in the following images (Fig. 1):

The objective of this case study is to develop techniques for reading speed analysis and concentration level detection and subsequently integration of such techniques with e-book systems to allow teachers to observe e-book reading in classrooms to keep track of students' levels of concentration and reading behavior and provide assistance at the right time when reading difficulties are detected. Today, touch screens and web cameras are standard equipment for tablet computers. As mobile technology grows more and more accessible, the concept behind this study can be regarded an approach to accomplish "teachers providing scaffolding and guidance at crucial moments" and "evaluation of authenticity of learning in assignments" as stated in the theory of using e-books in authentic learning.

### *3.2 Handheld Sensor-Based Vocabulary Games*

This case study is from a paper titled "*A Scaffolding Strategy to Develop Handheld Sensor-based Vocabulary Games for Improving Students' Learning Motivation and Performance*" published in *Educational Technology Research and Development*. The idea of using a "handheld sensor-based vocabulary game based on the scaffolding strategy" is proposed in the study to help university students in southern Taiwan with English vocabulary learning. The contents of the study are as follows:

Vocabulary is the foundation in language learning. Proficiency in a language requires vocabulary of a certain size. Traditionally, recitation and memorization have been emphasized in vocabulary learning, making the learning process a monotonous and boring activity. Trying a different learning strategy may increase students' interest in vocabulary learning and results. Cagiltay (2007) points out educational game apps have created many more attractive learning methods than those adopted in traditional teaching and also have enhanced students' learning motivation. However, inappropriate games can also have negative influence of students' learning. For this reason, how to design an appropriate game in line with a right learning strategy is particularly important (Chen and Hwang 2014; Hwang et al. 2014; Sung and Huang 2013). This case study proposes a learning game tool integrated with the scaffolding strategy called "handheld sensor-based vocabulary game" as an attempt to improve students' vocabulary learning motivation and results.

Figure 2 shows the front page of a game. There are four options: "Material" provides the vocabulary needed to complete the game; "Instruction" explains the game rules; "Story" tells the story of the game; and "Play" begins the game.

Once the game is started, the gyroscope in the handheld device detects the tilting angle to enable the player to play the game (Fig. 3).

Before the game begins, the player can choose the "Material" option to learn the vocabulary needed to play the game. The vocabulary, pictures and corresponding


**Fig. 2** Main menu of the handheld sensor-based vocabulary game (Huang et al. 2015)

**Fig. 3** Scene of the handheld sensor-based vocabulary game (Huang et al. 2015)

information are displayed to allow students to make associations between the vocabulary and related things or objects in order to enhance their learning motivation (Fig. 4).

When the "Story" option is chosen, the story behind the game is described so that students can understand the background of the story and game scenarios. Students playing the game have to operate the vehicle to get the fruit; they need to spell the vocabulary correctly within the shortest time in order to break through the barrier each time. Before students spell the vocabulary, clues are provided to be the scaffolding in accordance with the level of difficulty selected. This enables students to learn step by step and helps them learn the English vocabulary (Fig. 5).

The contribution of this case study is the design of a "handheld sensor-based vocabulary game" by adopting a tablet computer and tilting angle detection with the gyroscope. Different scaffoldings are provided to help students complete the English vocabulary learning assignment by using the handheld device. This is an approach to achieve authentic learning using e-books with "teachers providing scaffoldings and guidance at crucial moments."


**(a)** the material of coconut **(b)** the material of watermelon

**Fig. 4** Scene of the material (Huang et al. 2015)


**(a)** level one by tipping all letters and pronunciation **(b)** level two by tipping some letters and pronunciation

**Fig. 5** Use of scaffolding strategy in the game (Huang et al. 2015)

## 3.3 Electroencephalography

In this case study, brainwaves are measured to analyze the effect of the combined use of mobile devices and sensing technology to assess students' emotions in authentic learning. The tests are conducted as follows:

Examinations are important ways for teachers to evaluate students' learning results. For students, failing to get expected scores can cause pressure and anxiety. This study shows that computerized self-tests can help learners reflect on the contents of learning and also increase their learning motivation (Moridis and Economides 2012). However, it also suggests that the emotional condition of learners can be a key factor of effective learning. Therefore, many researchers have thought and discussed about designing emotional feedback systems. Application of an instant emotional feedback mechanism in a test system can not only reduce learners' anxiety but also help build up their confidence and thus improve learning results. Apparently, an appropriate feedback mechanism provided in a self-test system can help learners adjust their moods and benefit learning results.

Traditionally, measuring scales are filled out for assessment of emotions. The problem is that emotional conditions change constantly in response to different events that occur; hence, a technique able to measure emotional changes instantly and precisely is needed. This study indicates that neurological research methodology can be applied in studies of emotions and cognitive processes. The electric potential in the brain varies with changes of idea, emotion and desire, all caused by electric current changes and chemical reactions in the brain. EEG analysis can be applied to understand the mental state under certain awareness (Ahern and Schwartz 1985). Use of an EEG not only can immediately establish the behavioral condition and physiological changes of a student but also allow continuous measurement and recording of brainwave conditions. Therefore, an EEG is adopted in the study to monitor the brainwave changes of students caused by the applause feedback throughout self-tests in order to understand the changes in males and females during self-tests.

The study was conducted on 30 students (15 male and 15 female) of a university in southern Taiwan. The students were divided into a male group and a female group to take turns to complete assignments as the experimental group and the control group. Each test lasted about 23 min. The students were requested to answer every question within four seconds and also fill out the anxiety measurement questionnaire after completing the assignment. Throughout the experiment, each testees had to wear a 32-channel EEG cap, as shown in Fig. 6.

In the assignment for the experimental group, the testees were requested to operate the self-test system to take a self-test. When an answer is correct, the system immediately plays a recorded round of applause. When the answer is wrong, the system displays “Incorrect.” No sound effect is played in the assignment for the control group, however. Only “Correct” and “Incorrect” are displayed on the screen, as shown in Fig. 7.

An EEG is adopted in this study to monitor the brainwave changes of students caused by the applause feedback throughout self-tests in order to understand the changes in males and females. EEG analysis indicates that the Alpha 2 frequency of male students in the experimental group is higher than that of the female students. Figure 8 shows that male students have more red activated blocks than female ones, indicating that the applause feedback creates more positive emotions. Hence, the applause feedback has a larger effect on male students.


**Fig. 6** Testee wearing a 32-channel EEG cap

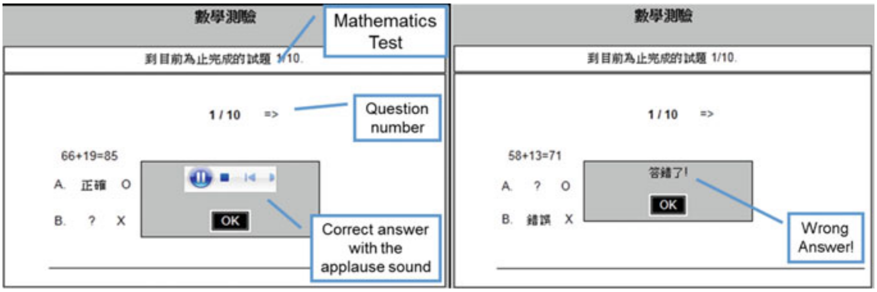


**Fig. 7** Self-test system

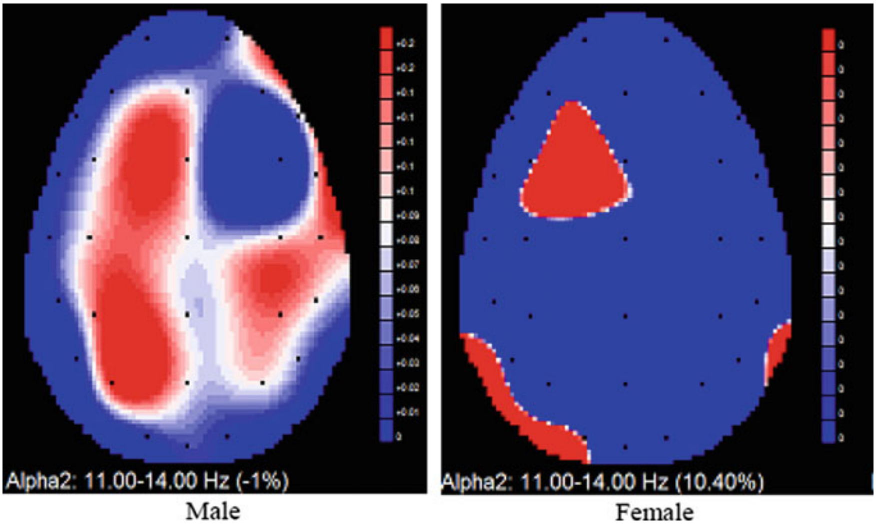


**Fig. 8** Images of activated blocks in the brains of testees

During the self-test process, the brain needs larger resources to complete each assignment. Figure 9 explains the effect of the applause feedback on male and female students. The delta wave (1–4 Hz) changes show that the delta wave value of males is at its highest (pink) when there is no applause feedback and at its lowest (red) when there is applause feedback. In contract, the delta wave value of females shows no significant changes (green, blue) whether there is applause feedback or not. This makes it evident that emotional feedback can help reduce negative emotions and anxiety in both male and female learners during a computerized self-test. Moreover, applause feedback can promote positive feelings and reduce anxiety in males.

The main contribution of this case study is the tablet computer–EEG combination to monitor the brainwave changes of students taking self-tests. Since the

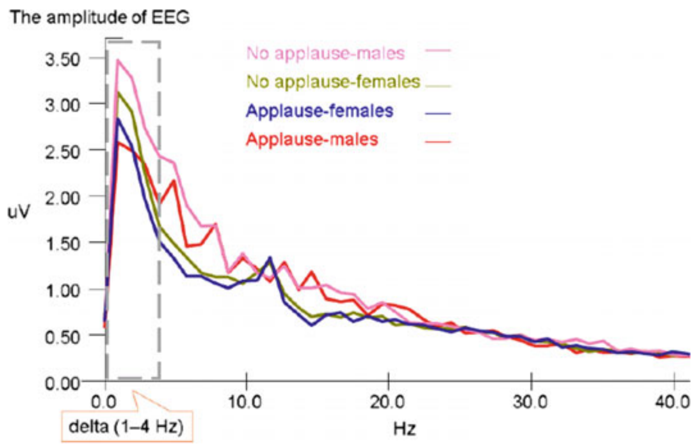


**Fig. 9** Brainwave changes of testees when getting applause feedback

concept of authentic learning stresses "provision of authentic scenarios able to reflect application of knowledge in reality," measurement of learners' emotions and interactions in authentic scenarios are necessary. Therefore, the tablet computer–EEG combination may help develop emotional feedback techniques with regard to e-textbook reading and lead to creation of other scenarios for authentic learning.

## 4 Conclusion

With the development of e-books in full swing, more and more teachers and researchers have also taken action to be part of it. The first problem they encounter in application of e-books in teaching is incorporation of appropriate scenarios with e-books in learning activities, so that they can rethink how to apply e-books in education. The authentic learning theory is a teaching method with the main purpose of enabling students to use knowledge and skills they have learned to solve problems they encounter in reality (Herrington 2006). This coincides with the effort in education today to train students to develop abilities that they can actually apply. Therefore, how e-books can be useful and have real effects is an important issue. For this reason, "Interactive Electronic Books for Authentic Learning" is adopted as the main theme of this chapter to discuss authentic learning and the feasibility of integration of scenarios with e-book techniques to help readers understand different new technologies that can be applied in various scenarios to provide references for further consolidation of authentic learning and e-books.

Detection of learners' physiological and mental conditions is required throughout the learning process. Therefore, the author has adopted three case studies to explain how e-books and sensing techniques can be combined to detect the physiological and mental states of learners, including tacit behavior (emotions, for example) and explicit behavior (such as level of concentration, reading behavior), and provide the scaffolding in accordance with the learning behavior. The three abovementioned scenarios, respectively, correspond with "teachers providing scaffoldings and guidance at crucial moments," "provision of authentic scenarios able to reflect application of knowledge in reality" and "evaluation of authenticity of learning in assignments" as stated in authentic learning theories. By using them, implementation of authentic learning with e-books can perhaps be fully brought to realization. In the future, as sensing techniques and interaction technology become more advanced, e-books may be able to provide teachers, students and peers with more diverse interactive flexibility and inspire teachers to come up with creative teaching plans. Thus, use of e-books in authentic learning will be enriched and the potential advantages of mobile technology can be exercised to build friendlier learning environments.

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# Use of the Collaboration-Authentic Learning-Technology/Tool Mediation Framework to Address the Theory–Praxis Gap

**Alan Amory**

**Abstract** To develop a practical solution to learning with technology a collection of case studies related to the use of education games, a course and a professional development opportunity are discussed. Each case study is presented to explore the use of a collaborative-authentic task–tool (technology)-mediated (CAT) framework. This framework is based on neo-Vygotskian ideas of learning. The case studies on the use of games in education show how collective solving of a game puzzle helped overcome misconceptions held by players. A course on the use of ICTs in teaching and learning, based on the CAT framework, showed that student performance was superior to didactic instruction courses. Academic professional development based on the CAT framework illustrates new ways in which higher education models could be devised. In many of the case studies, the concept of tool mediation is easily misunderstood and therefore requires appropriate scaffolding of the learning activities by the lecturer or teacher. This collection of case studies supports the idea that the use of the CAT framework is a practical way to design teaching and learning with technology.

**Keywords** Collaboration · Authentic learning · Tool mediation · Learning with technology

## 1 Introduction

With every new technological innovation comes a promise of a transformed educational practice. But the most practiced form of education is still learning through acquisition (teachers deliver information to students) (Laurillard 2012). This is particularly true in learning designs that use online systems, such as Learning Management Systems (LMSs) (Reeves et al. 2004) and Massive Open Online

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Course (MOOC) systems, which typically replicate traditional classroom instruction practices. These positivist learning designs foreground information, content and technical issues rather than social cognitive development. In addition, the use of technology as the panacea to solve all teaching and learning problems rather that an emphasis on the appropriate pedagogical use of technology in the classroom is a universal problem (Amiel and Reeves 2008). There are other ways that technology could be used in learning task design, for example, through the affordances offered by educational technologies.

Affordance was first coined by Gibson (1977) while developing an “ecological” approach in opposition to cognitive approaches and “refers to the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used” (Pea 1993 p. 51) To create effective and usable computer systems Norman (1988) suggested that a number of affordances could be considered during software design, including visibility, constraints, affordances, natural mappings, and feedback. Conole and Dyke (2004) made use of Pea’s definition to explore how the affordances of educational technologies could be articulated into a taxonomy, and how the understanding of such affordances might be used to support learning and teaching. These authors suggested that a taxonomy of educational technological affordances include accessibility, speed of change, diversity, communication, collaboration, reflection, multimodal and nonlinear, risk and uncertainty, immediacy, monopolisation, and surveillance. Also, “affordance descriptors are meant to offer an example as to the fundamental, pragmatic, and functional level at which affordances should be identified in order to be suitable for matching to the affordance requirements of various learning tasks” (Bower 2008, p. 6)

Educators do not universally accept the uses of affordances. Ecological positions need to be considered as cultural context that influence the understanding of the affordances (McGrenere and Ho 2000). Furthermore, the affordance concept has become too ambiguous to be of analytical value and the animal–object relationship over evolutionary scale might have little relevance to moment-to-moment individual interactions unless “we are willing to abandon constructivist values in order to explore ‘inherent properties’ in a positivistic sense” (Oliver 2005, p. 412). The use of technology may have nothing to do with its design or affordances, but may be due to our individual belief systems, often cognitive and reductionist, of what constitutes teaching and learning (Amory 2007). However, we can re-conceptualise teaching and learning with technology within a social reform model of education, emphasising our social nature of learning within and as part of our communities (Savin-Baden 2000; Stetsenko 2008, 2004). Knowledge should rather originate *out of* social practice that includes cultural tools, *through* social practices of tool exploration and inquiry, and *for* social practice (Stetsenko 2013). The work presented here aligns with the Cultural Historical Activity Theory (CHAT) (Engeström 1987; Leont’ev.1978) predicated on the social constructivist learning theories of (Vygotsky 1978, p. 19). The Collaborative-Authentic Learning-Technology/Tool Mediation (CAT) framework (Amory 2014), which is aligned to Laurillard’s conversation model (2012), is presented and then used as a heuristic to evaluate the use of technology in teaching and learning.

## 2 The Cat Framework

A number of important themes are part of Vygotsky's (1978) theory of child development. Social development precedes individual development. The child learns everything twice: first on the social (between people—interpsychological) and then on the individual (inside the child—intrapsychological) plane. In addition, Vygotsky defined the zone of proximal development as the distance between the actual and potential developmental levels determined through problem-solving under the guidance of more knowable teachers and peers. Social network analysis research shows that participation in learning communities improves academic performance (Gašević et al. 2013; Rizzuto et al. 2009), persistence (Thomas 2000), retention (Eckles and Stradley 2012), and creativity (Dawson, Tan, and McWilliam, 2011; Perry-Smith and Shalley 2003). Thus, collaboration is the first component of the CAT framework.

For meaningful learning to take place, the object of the activity, the most important component of activity theory (Kaptelinin 2005), needs to be clearly defined, as it is the prime unit of analysis in an activity system (Engeström 2001). In support of (Iverson et al. 2008), Amory (2014) posited that effective learning designs include authentic learning tasks (Brown et al. 1989; Newmann et al. 2001; Reeves et al. 2004; Smeets 2005) and could be viewed as the *object of the activity*. Brown et al. (1989) suggested that situated cognitive apprenticeships included collective problem-solving, displaying multiple roles, confrontation of ineffective strategies and misconceptions, and developing collaborative work skills as part of authentic activities. Means and Olson (1994) argued that within authentic environments technology has the power to support both students and teachers to solve complex problems. Building on the concepts of situated cognition, Herrington and Oliver (2000) posited that instructional designs that include educational technology should make use of authentic learning environments. In addition, Smeets (2005) proposed that for the learning environment to be successful it should include rich contexts, authentic tasks, active, autonomous learning and co-operative learning. Therefore, in the CAT framework, the object of activity is an authentic learning task.

Lastly, a core component of Vygotsky theory is that interaction with the social and physical world is mediated by tools that are either physical (such as pencils and technological artefacts), or psychological *signs* and *symbols* (especially language). Tools are object-orientated to material activity, while signs and symbols are part of social and intrapersonal interaction used to solve problems (that is, part of higher cognitive functions). But depending on the context, a material tool could function as a tool, a sign or both—all artefacts could therefore be seen as both material and conceptual, as parts of our world, modified over historical time, and shaped by human activity (Cole, 1996). In addition, tool mediation can either be explicit (the intentional introduction of a tool, or sign, into an existing activity) or implicit (involves signs, especially language) (Wertsch 2007). In the CAT framework, educational technology should always function as a mediating tool (a learning *with* technology position) and never be the object of the activity (a learning *from* technology position).

**Table 1** Collaboration-authentic task—tool mediation (CAT) framework

| Collaboration | Authentic learning | | Tool/Technological |
|---|---|---|---|
| • We learn from each other<br>• Social media connects us<br>• Together we create new ideas, connections and products<br>• Course facilitators create environments for social change | • Have real-world relevance<br>• Are ill-defined<br>• Are complex<br>• Provide opportunities to examine from different perspectives<br>• Provide opportunity for collaboration | • Provide opportunity for reflection<br>• Are integrated across different subject areas<br>• Are integrated with assessment<br>• Yield polished products<br>• Allow for competing solutions and outcomes | • Information stream<br>• Enabler of communication<br>• Empowering collaboration<br>• Information transformation tool<br>• Professional tool |

Therefore the CAT framework includes three components: collaboration to support interpsychological interactions and intrinsic mediation, authentic tasks as the object of the activity, and technological tools to support explicit and implicit mediation (Table 1). The authentic learning tasks are based on the work of Reeves et al. (2004) rather than the more recent conceptualisation by Herrington, Reeves and Oliver (2009), who describe the system using more abstract concepts, thereby making the concept more difficult for inexperienced lecturers.

Depending on the objectives of a study, case studies can be divided into three types: intrinsic case studies that investigate the uniqueness of the cases, instrumental case studies that are concerned with advancing theory, and collective case studies that make use of any number of cases as part of an instrumental case (Stake 1995). A collective case study approach is taken here to evaluate the use of the CAT framework in educational technology in learning and teaching. A number of case studies allied to the CAT framework are explored to show that the use of appropriate theoretical approaches to learning design can address issues related to learning from technology (instruction) and overcome the theory–praxis problems often associated with online or e-learning.

## 3 Case Studies

Case studies reported here include a number of examples of the use of educational games in teaching and learning, an honours course on educational technology for teachers and a professional development workshop for academic faculty staff members.

### 3.1 Educational Games as Authentic Learning Tasks

Overcoming misconceptions through game play was a primary theme of much of research done by my students and myself into the use of technology in teaching and learning. Adams (1998) used an instrument where each question included three parts: multiple-choice factual question, multiple-choice reason for answer, and confidence level.

After one hour of playing an adventure game (Zadarh) Adams found that there was no improvement in student understanding of misconceptions related to photosynthesis and respiration, and suggested students needed to change their learning strategy for any improvement to be realised. Extending this work, Foko and Amory (2004) worked with small groups of students in northern KwaZulu-Natal who played on their own (as was the case with the work done by Adams), played in groups with discussion between the players and facilitator for 8–10 h and then took either a written or oral test (Table 2).

Students who played with a partner overcame many of the misconceptions the game was designed to address (increase in the number of correct answers) and more so with the support to improve their understanding of the instrument item. These results clearly indicate the game puzzles, acting as the authentic tasks, support student understanding of photosynthesis and respiration when they played together. Social dialogue and solving puzzle mediated knowledge construction.

A second study investigated how young Sowetans (14–18 years old) played a game on the biology of important diseases including HIV/AIDS and tuberculosis (Amory 2010). As in the previous example, the adventure game narrative was driven by authentic puzzle-solving activities. The young Sowetans played in groups of three or four participants that included both sexes with facilitator support for 10 h over a number of days. All participants completed the game except one group who insisted on playing on their own.

During game play, participants kept a personal reflective journal and after game play they answered an instrument designed to determine the misconceptions related to the diseases and participated in a round-robin discussion. Statistical analysis of their questionnaire answers showed that these young school students performed in a similar manner to first-year university biology students and better the first-year non-biology university students (Table 3). Analysis of their journals and group discussion illustrated that they understood that solving the game puzzles mediated

**Table 2** Playing Zadarh to overcome misconceptions related to photosynthesis and respiration (from Foko and Amory 2004)

| Treatment | Correct answer (%) | Correct reason (%) |
|---|---|---|
| Individual play—written evaluation | 57.9 | 28.4 |
| Group play—written evaluation | 75.0 | 42.5 |
| Group play—oral evaluation | 90.5 | 50.0 |

**Table 3** Performance by teenagers measuring their understanding of the biology of a number of diseases after game play compared to first-year university students (from Amory 2010)

| Group | Mean score ± SD (%) | | |
|---|---|---|---|
| Teenage participants | 57.1 | ± | 8.9[a] |
| First-year biology students | 61.4 | ± | 10.2 |
| First-year non-biology students | 37.6 | ± | 8.1[a] |

[a]Significant difference, t test = −7.982, DF = 116, $p < 0.001$

their learning, allowed them to identify the object of the activity (learning about diseases) and suggested ways in which they might help their community.

In a third example, third-year B.Ed. students (n = 184) were introduced to the theories related to authentic learning and an object-tool-social framework (a simplified versions of the CAT framework) (Amory 2011). They played the same game (biology of important diseases) in pairs as one of the course's authentic tasks. The students were told to find four cards and four keys to solve the final game puzzle, to think about the motives related to the playing of the game (identification of the object of the activity) and to analyse their actions using the object-tool-social framework. Students submitted a portfolio for their final examination assessment and were asked to select three of the 11 course authentic tasks to demonstrate what they had learnt in the course. Their performance in a number of the authentic tasks, and the relationship between their performances in these tasks and the tasks they selected for their portfolio were quantitatively analysed (Table 4). Their written submissions on the game play task and their examination portfolio submissions were quantitatively analysed deductively against the object-tool-social framework to gain insights into what they learned through their game play.

Based on the post hoc test, which did not assume equal variance, the means were clustered into two general groups, the chapter review exercise belonged to both

**Table 4** Performance by third-year students in course work authentic tasks and examination portfolio tasks. Column 1 lists authentic task, column 2 lists the per cent of group a choosing specific task as relevant for their learning, column 3 lists the average percentage obtained by the group for the task, column 4 the standard error, column 5 the statistical similarity in performance of the different tasks (ANOVA $F = 22.61$, $p < 0.001$; Levene = 13.71, $p < 0.001$; Post hoc test = Tamhane; from Amory 2011)

| Authentic task | % | Mean | SE | Group |
|---|---|---|---|---|
| Test | 4.0 | 72.0 | 1.7 | 1 |
| Computer LAN | 16.4 | 69.2 | 1.2 | 1 |
| Education game | 8.2 | 65.3 | 1.2 | 1 |
| Interactive whiteboard | 19.2 | 64.9 | 1.2 | 1 |
| Chapter review | 7.8 | 63.1 | 1.9 | 1, 2 |
| Authentic learning | 13.6 | 56.0 | 1.4 | 2 |
| SA classroom design | 10.8 | 55.3 | 1.4 | 2 |
| Classroom design mind map | 14.2 | 49.0 | 1.1 | 2 |
| Other | 6.0 | | | 2 |

groups. Students who understood the theories associated with authentic learning and object-tool-social concepts scored higher for these tasks (group 1) and were more likely to select these tasks for their portfolio (for example the educational game task). Content analyses revealed that students were able to identify the object of the activity, but also made reference to tool mediation, collaborative learning and authentic tasks. However, a single student realized that the primary object of the activity was to "evaluate [the] game for learning". Pre-service teachers demonstrated that they understood the importance of social interactions is undertaking authentic tasks and solving game puzzles. In addition, they understand tool mediation. For them, an interaction with game puzzles led to knowledge construction.

The construction of education games that include authentic story lines and puzzles allows collaborative tool-mediated knowledge construction. This is especially true when the game puzzles are designed to address specific misconceptions or conceptually challenging content areas. These examples illustrate that the design of educational games that include authentic activities (game puzzles) mediated learning in small and large groups of students. However, what is important in these situations is the role of the teacher, or facilitator, who scaffolds and supports students in their collaborative explorations. More specifically, discussions between game players intrinsically mediated their understanding; the games, puzzles and game artefacts supported knowledge production as they function as mediating artefacts and not as the object of the activity; and the introduction of games puzzles into a learning activity acted as the extrinsic mediator. Likewise, a CAT framework designed course that includes a number of related activities supports collaborative tool-mediated knowledge construction.

## *3.2 Course Design*

Amory (2014) used an educational design approach (McKenney and Reeves 2012) to develop a course on the use of Information Technology and Communication in teaching for Bachelor of Education (Honours) students. The course included ten 2-h contact sessions and required the students (district officials and teachers) to spend at least an additional 180 h on assignments. The course included five authentic tasks:

- Evaluation of the school's e-maturity-output: a Google document;
- Use of tools available to support the development of e-maturity-output: a Google presentation;
- Exploration of the knowledge, skills and attitude of current learners-output: a MindMap diagram);
- Use of Open Source, Open access and Open resources in teaching and learning-output: a Weebly web site; and
- Plan for a future education system-output: a StoryBoard document.

Tools used to create assignment outputs ranged from the familiar (Google documents) to the unfamiliar (StoryBoard). Each task required a group submission followed by a class discussion. The final summative portfolio required each student to provide a brief introduction on what they thought they had learnt, a selection of three of two or three assignments that they could improve to take into peer and lecturer comments, and provide a critical review of the course. Results reported included student opinions on the course, an assessment of the course using the authentic learning principles and an analysis of their performance.

Students liked finding relevant information, thought that it was important to work in groups but wanted to select who was part of the group, and thought they learnt more at the end of the course than they expected (Table 5). But, in contradiction, they also wanted additional lectures and more reading materials to be provided.

Except for reflection, all the components of authentic learning were rated highly by the participants (Fig. 1). Students did not seem to appreciate that the discussion of each topic in class and the detailed comments made by the lecturer were part of reflective activity. In addition, they thought that there was insufficient emphasis placed on the production of the polished product. However, they appear not to understand that the portfolio was the primary instrument for reflection and an opportunity to produce improved work.

A 1 x 3 repeated-measure analysis of variance (RM-ANOVA) was applied to test for significant differences between the final examination results of three different courses (educational ICT, research methodology, and education theory) (Table 6). The educational ICT and research methodology courses were similar in design and made use of authentic tasks while the education theory was a didactic lecture course. Amory (2014) found from a pairwise comparison that the education ICT and research methodology courses were significantly different to the education

**Table 5** Analyses of students (n = 27) to a number of statements on the design and delivery of the ICT course (from Amory 2014)

| Item | Rating |
|---|---|
| Finding information for myself is a good way to learn[a] | 5.36 ± 0.18 |
| Working in groups supported my learning | 5.05 ± 0.32 |
| Working in groups is effective | 5.00 ± 0.27 |
| By the end of the module, I learnt more than I expected[a] | 4.82 ± 0.28 |
| I also learnt from information that other students found | 4.77 ± 0.25 |
| I did not like the way the module was presented in the beginning, but I am now comfortable with it[a] | 4.27 ± 0.35 |
| I would prefer to be given all my learning materials[a] | 3.95 ± 0.35 |
| I think the lecturer should have taught more[a] | 3.86 ± 0.35 |
| I would have preferred that the classes were more structured | 3.41 ± 0.35 |
| The lecturer should decide who are in groups[a] | 1.91 ± 0.27 |

[a]Wilcoxon significance <0.005 (compared to results from a 2007 group)

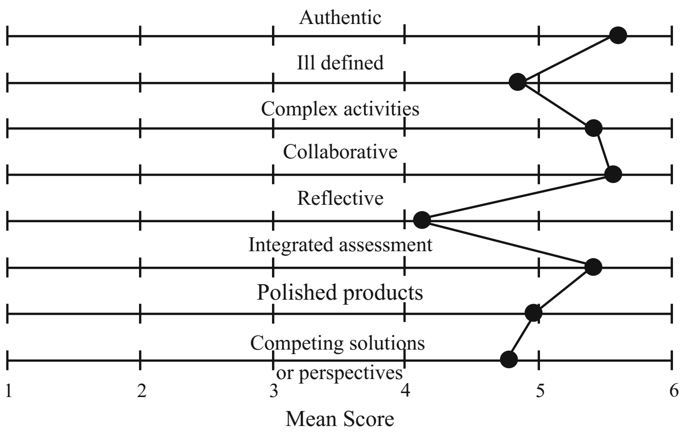


**Fig. 1** Student assessment of the authentic task design principles (redrawn from Amory 2014)

**Table 6** Descriptive analysis of different honours courses (mean ± standard deviation; from Amory 2014)

| Course | Final mark |
|---|---|
| Educational ICT | 60.73 ± 10.66 |
| Research methodology | 56.07 ± 16.48 |
| Education theory | 50.07 ± 11.33 |

theory course ($p < 0.0001$ and $p = 0.006$, respectively) and that the educational ICT and research methodology courses were similar ($p = 0.25$).

This case study illustrates that collaboration allied to authentic tasks and technological tools mediated new understandings. The introduction of authentic learning was challenging for students who are used to the didactic lecture but with time they come to prefer the approach. More importantly, courses that include components of authentic learning lead to improved performance and student attitudes to learning. The last case study explores how academic staff members responded to a professional development opportunity based on the CAT framework.

### *3.3 Academic Professional Development*

This case study is concerned with the professional development of academic members from a South African University in the use of technology in their teaching, learning and assessment practices (Amory 2013). In this institution, learning was conceptualised as: becoming a practitioner of a knowledge and professional domain; that information-oriented (recitation of information) approaches limit optimal learning; and ICT should extend contact teaching in innovative and digitally rich ways (Amory et al. 2008). However, prior to 2012, professional development in the use of ICT in teaching, learning and assessment was limited to training (a learning *from* technology approach). The use of the CAT framework to support professional development fostered a new approach (a learning *with* technology approach). The workshop included two authentic tasks. Participants acted as students (authentic task 1) and then as learning designers (authentic task 2). During the workshop the participants created a number of artefacts, including the use of a CAT framework instrument to review a number of papers on the pedagogy associated with the use of games in teaching and learning, the design of a learning task, and an evaluation of the workshop. Participants also used the data from the games evaluation exercise to create graphs and a mind map as part of the first activity. Their learning designs were analysed by Amory (2013) deductively using the CAT framework.

The participants were able to use the CAT framework instrument (tool mediation) to identify pedagogical practices, plan learning activities and evaluate the workshop. However, explicit and implicit mediation involving either tool or sign were not fully appreciated. The use of ICT as tool mediator was mostly limited or superficial. Participants found the workshop challenging but of the 29 comments received, while two were negative and two dealt with administrative issues, the rest were positive, for example:

> An insightful workshop that helps us understand how simple changes to thought and application can help in getting students to learn something old in a new way.

> I loved the workshop! I so much appreciate the departure point of authentic learning, focused on skills and perspective, rather than content. I enjoyed the engagement, and the discussions at the end. Maybe mid-way through the workshop a discussion session would be useful.

## 4 Discussion

The case studies selected for this chapter explored the effective use of the CAT framework as a heuristic to understand the use of games to overcome misconceptions, to design and present a fourth-year course to education students, and to design a professional development for academic staff members. The primary aim was to show how collaborative engagement with authentic tasks mediated by educational technologies can support learning and overcome the theory–praxis divide. In addition, the examples highlight how the use of ICTs can enrich teaching in innovative and digitally rich ways. These collective case students support declarative and procedural design principles based on the work of Amory (2014). The declarative principles include, knowing that:

- Cultural Historical Activity Theory supports course design and evaluation;
- Authentic learning tasks promote effective learning; and
- Educational technology (as tools) mediates knowledge construction.

The following procedural principles apply:

- Use the CAT framework as a heuristic to conceptualise game puzzle, course and workshop design and evaluation;
- Implement authentic learning tasks as the object;
- Incorporate educational technologies as tools to facilitate knowledge construction (a learning *with* technology position);
- Reject course designs when education technology functions as the object (a learning *from* technology position); and
- Use the CAT framework as a device to evaluate learning activity or course design.

The question that these collective case studies attempt to answer is that based on appropriate theoretical foundations a practical framework can support the creative use of technology to support collaborative learning rather than supporting recitation of information as a means of knowing.

Herrington and Parker (2013) suggest that complex authentic tasks can be designed but require a substantial amount of effort by collaborating students. Also, emerging technologies should be included in authentic tasks as a social cognitive tool, in other words to support tool-mediated knowledge construction. They also point out that for such an approach to succeed it requires a commitment from lecturers and teachers to provide scaffolding and support, which is a significant task.

Likewise, the use of authentic learning allied with profession development requires considerable effort to transform teaching from a didactic information distribution paradigm to one that makes use of authentic tasks (Teras and Herrington, 2014).

The use of technology to mediate (as a cognitive tool) collaborate problem-solving (authentic) tasks, the CAT framework, provides a practical approach to addressing the theory–praxis divide.

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# Analytics in Authentic Learning

**Vivekanandan Suresh Kumar, Kinshuk, Colin Pinnell and Geetha Paulmani**

**Abstract** Learning is a marked change in the conceptual representation of the world, in naturally intelligent entities, such as humans, as well as in artificially intelligent entities. Analytics aims at the generation of situational awareness, specifically, moments of insight that effect such a marked change and the enablers of the change. In that, Learning Analytics is the study of detection, analysis, and generation of moments of insights about learning experiences of naturally or artificially intelligent entities. It enriches learning experiences as a measurable consequence of these moments of insights. In infusing authenticity to learning experiences, this chapter discusses abstraction-oriented pedagogy at one end of a continuum and reality-oriented pedagogy at the other end and offers a characterization of this continuum.

**Keywords** Learning Analytics · Pedagogy · Authentic learning · Abstraction-oriented pedagogy · Reality-based pedagogy

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# 1 Introduction

Traditionally, educational institutions left the responsibility of meeting individual student needs, if at all recognized, to the instructors. In recent years, educational institutions are shifting focus to supplement traditional instruction with personalized learning experiences. Both these styles of learning experiences are designed to include a variety of study activities. The goals of the activities have also shifted focus to target both subject matter competence and cognitive competence.

To gauge learning progress, educators measure observable learner outcomes and behaviours as a by-product of these study activities as well as the outcomes of evaluation activities. These measures offer clues to the educator on learners' capacity to study, effectiveness of interventions, and growth of subject matter competences. These measures also offer clues to learners themselves about their competences, their misconceptions, and at times their study efforts.

The educational process, in most contexts, can be defined as an interplay between study activities and assessment activities. Contemporary educational technology has made it possible to supplement these activities in online environments with automated data collection. In doing so, a much finer granularity of the data is being collected from study and assessment activities to allow for precise and verifiable inferences about learner competences and instructional effectiveness. In addition, contemporary educational technology has enabled institutions and administrations, which create, deploy, and govern curricula, to critically and continuously evaluate the impact of study activities and assessment activities on learner competences and instructional effectiveness.

Abstraction-oriented study activities involve pedagogies that offer highly abstracted view of the learning outcomes, allowing students to develop generalized approaches to study and gain generalizable skills. Students who are exposed to such skills can also be trained to triangulate and hone these skills on context-specific applications in the real world. For example, one can learn about software engineering skills in terms of theories and then investigate the coding habits of programmers in real-world projects. In abstraction-oriented activities, the degree of authenticity is expected to be marginal.

On the other hand, study activities can also be immersed in reality-based pedagogy that immerses students in virtual, augmented, or even reality-oriented experiences. For example, one can learn about software engineering skills from direct observations of teams involved in the development of real software projects and then investigate theories related to these observations. That is, students can be placed in realistic learning situations, to experience it in-person, or experience it using a virtual reality environment, or interact with it through an augmented reality environment. In reality-oriented activities, the degree of authenticity is expected to be non-trivial.

The goal is for the students to eventually achieve both generalizable skills and specialized skills in both subject matter and cognitive domains. To achieve this goal, Learning Analytics can personalize and regulate the pace, the interleaving, and the degree of authenticity of each study activity.

This chapter reviews aspects of Learning Analytics in the next section, followed by its application. Authentic learning is discussed in Sect. 4 followed by concluding remark.

## 2 Learning Analytics

Learning Analytics is a relatively new field within education. Investigations into the psychology of learning and motivation have discovered that many of the practices that make up the modern learning context are inefficient, ineffective, or at times directly contrary to the goals of an educational system. This suggests that these traditional learning environments, despite their long lineage, should be augmented with those that use a full, modern understanding of learning and organizational efficiency.

The creation, administration, and assessment of assignments and examinations, the evaluation of learner activities within a classroom, the design of curricula and learning plans—all of these are established, observable practices within traditional instruction. The ability to observe study activities and assessment activities at finer levels of granularity and the ability to translate these observations into meaningful learning outcomes have resulted in increased levels of research, development, and application of Learning Analytics in traditional environments (Almosallam and Ouertani 2014). Ubiquitous computing and sensing further provides us with a flood of potential data on the behaviours of learners about the process of learning itself (Crawford and Dana 2011).

### *2.1 What Is Learning Analytics?*

Learning Analytics does have its own unique characteristics which deserve special attention (Chatti et al.2012). While analytics applies equally to human learning and machine learning, discussions in this chapter will focus only on human learning.

Analytics aims at the generation of situational awareness, specifically moments of insight. Learning Analytics aims at the generation of awareness of the states of knowledge within a learner with a view to promote positive learner growth.

Learning generally proceeds slowly and gradually, through practice, repetition, and study. However, learning is also characterized by epiphany events—bursts of insight in which the student "gets it", the proverbial eureka moment. The periods of study and practice are in preparation of these moments of clarity.

Analytics focused on the learning process therefore concerns two phases: the slow, gradual equilibrium stages, punctuated by dramatic jumps in competence in insight stages. Like the saltation of pebbles on a river bed, learning can be said to proceed in hops from one level to the next. Learning Analytics is concerned with providing progress awareness during equilibrium moments with an overall goal of generating insight to help the learner propel themselves to higher levels of knowledge (Arnold and Pistilli 2012).

Some confusion exists in the difference between the practice of analytics and the practice of analysis as well. These two words are closely related, but the difference between them is important in the context of both educational analytics and general analytics.

Analysis, in general, is used to describe the process of using a mathematical or statistical process to convert input data into output information, with the implication that the output is useful. In going through an analysis, the researcher usually poses a question, conducts an investigation using a specific process, and finds an answer to that question. Notably, the process used to find the answer is specific—the process of conducting a regression test is different from a Chi-squared test, for example. Rarely, a researcher may already have the data sets but then creates a new method of statistical analysis, a model, to find answers hitherto unknown within the data sets.

Analytics exists overtop of this view of analysis towards insights. Analytics considers each analytical process available as a potential tool to find an answer, a peek into an insight, and is concerned with the appropriate selection of these processes considering the information available and questions being posed. With this understanding, the researcher conducting an analysis can also be said to be engaged in analytics, provided that the researcher has wilfully chosen insights as goals of his/her investigation.

Further, analytics in the context of big data—in the context of large, loosely organized, self-similarly arriving data sets—has further implications. The data volume is very large and is constantly changing. The queries being asked of this data are not known in advance. Because of this, any analytics or analytical process being done on big data happens on demand. Data curation and processing ahead of time are often not possible. Analytics, therefore, implies a real-time, on-demand factor of analysis.

## 2.2 Types of Learning Traces

A learning trace is the real-time, dynamic record of all activities undertaken by a learner within a learning system. In general, a learning trace is a network of observed activities—study activities and/or assessment activities—that offer a particular measurement on learning. This tends to focus on students but also includes teachers, administrators, tutors, and anyone else connected to the system.

It would be incorrect to consider a learning trace to be the same as a transcript or record of education. These are important components of a learning trace, but are insufficiently large to consider as a proper trace. Real-time data must be included in some manner for the records to be considered as an appropriate learning trace, for one of the characteristics of a learning trace is finer granularity—it must capture data on a finer scale, so that not only can outcomes be recorded but also the behaviours leading up to those outcomes. Contrast this to a transcript of grades for a course, which contains the outcome of evaluation but keeps no record of what actions led to those outcomes. This preservation of context is the most important component of a learning trace.

Learning traces can be divided roughly into outcome metrics and behavioural metrics. These behaviours may or may not lead to outcomes, however. Measuring behavioural metrics is one of the key strengths of Learning Analytics over traditional systems. Though traditional educational settings record many outcome metrics, they do not record behaviours; rather, it is very difficult—if not impossible—for them to record behaviours objectively.

Outcome metrics may include metrics such as human-evaluated competence scores such as grades for assignments or examinations, computer-evaluated competence scores for work-in-progress, evaluations of achievement of learning goals, educator efficacy surveys, course efficacy surveys, grades for participation, grades for attendance, and other metrics. Note that not all of these are in real time, but they are all concerned with the success or failure of some aspect of the educational context.

Behavioural metrics may include such metrics as pause duration in typing, speed of typing, speed of scrolling in a webpage, eye movements, body heat or other biometric information, daily attendance, attentiveness, questions asked, language used in forums or in classroom, time and duration of stay at course websites or online resources, use of lab resources, and many others. Unlike the outcome metrics, these tend to have a much larger real-time component and are less concerned with success or failure, instead being concerned with the fine-scale behaviours of the participants (del Blanco et al. 2013).

## 3 Applying Learning Analytics

A computational model is network of variables and relationships, where values of variables and relationships can be computed. Educational systems have traditionally built competence computational models. These competence models are built with data obtained from manual evaluation of assignments and examinations and are aggregated into overall grades, or assessment of competence. Sometimes these models have included elements such as participation in class, attendance, and other behavioural information, but in general the models in traditional systems have been simple and reductive, relying on the attention of a set of educators to interpret fine-scale behaviours within the learning.

Instead of relying on a single competence model of learning, a sophisticated Learning Analytics platform can maintain a larger set of computable models. For example, in addition to competence models, learners may also have models of their level of motivation, their emotional states regarding the educational material, use of learning strategies, self-regulation techniques, and others (Blikstein 2013). Multiple models of learning can be constructed, each with its own focus and limitations (Barber and Sharkey 2012; Blikstein 2013; van Harmelen 2006). Interactivity models attempt to capture this complicated set of interactions between people (Teplovs et al. 2011; Ferguson and Shum 2012). Communication models are largely interested in determining the meanings of messages embedded in interactions and the importance of the choice of medium (e.g. twitter) (Teplovs et al. 2011). These models may be categorized into groups depending on the overall goal of the models.

Just as Learning Analytics can be considered to have varying scopes, so too do the models within the model store of a Learning Analytics platform. Precise models (see Fig. 1) exist at the fine scale of analytics, concerned with data pertaining to a single individual participant within the system. These could be considered to correlate with the transcript of grades for an individual student in a traditional system.

Contrasting with these models are aggregate models (see Fig. 2), which consider contemporary knowledge as observed from the literature. The specific scope may vary depending on the question being asked or model required; it may consider anything from learner pairs to the behaviours of entire educational institutions and anything between.

A context-aggregate model captures the frontier of a research topic (e.g. self-regulated learning) as reported in the literature. The corresponding context-precise model captures the study experiences of a student, in terms of learning traces experienced by that student in that research topic.

Input for context-aggregate model can come from different publications, as indicated by different coloured connections between variables in Fig. 2. Learning

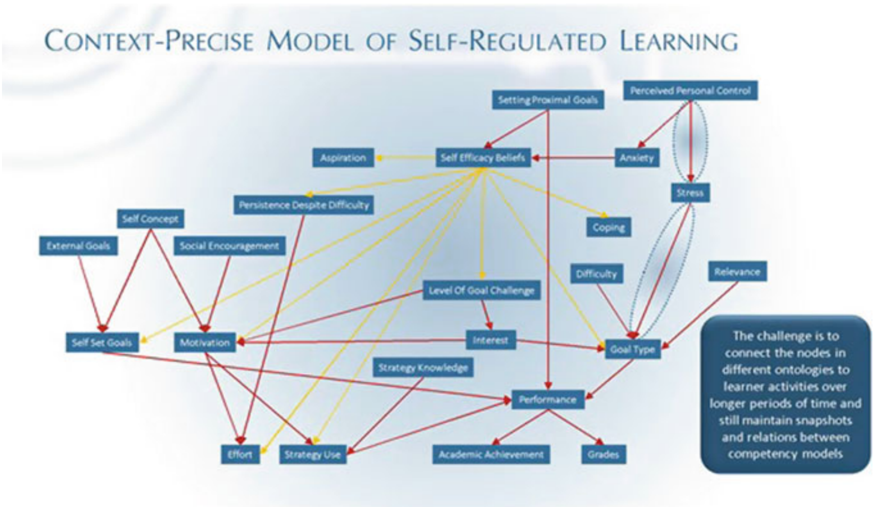


**Fig. 1** A sample context-precise model

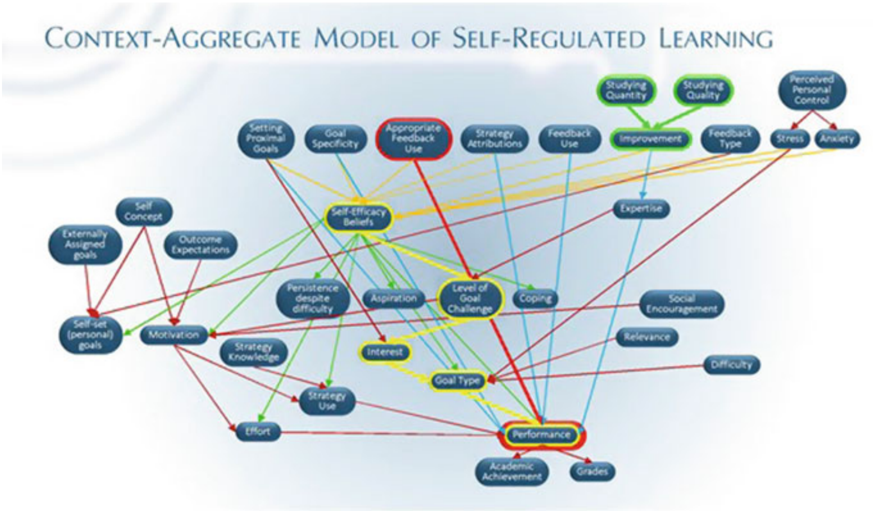


**Fig. 2** A sample context-aggregate model

traces are assembled from as many metrics as possible, as accurately as possible, and as often as possible (Cuzzocrea and Simitsis 2012).

An important difference between these models and the models generated by a traditional learning system is the automated generation of, and update of, learning models. Traditionally, models are constructed over the course of a semester by the gradual accretion of manual data. A Learning Analytics platform can construct and update its models in real time as information is made available to it, and requires minimal or no manual intervention.

Measurements concerning educators, tutors, and other participants can also be included in the system as components of computable models, allowing these traditional methods to coexist as part of an analytics platform.

## *3.1 The Flavours of Insight*

Learning Analytics identifies three distinct types of insights, each of relevance to understanding learning progression. First amongst these is the detection of moments of learning insights already experienced and elucidated by others. This is akin to applying someone's data set on someone else's computational model to expose insights that have already been garnered. Understanding the moment of expression of an existing insight can be crucial information, especially if that expression occurs within a particular trace of learning episode instead of outside of that episode. Insight expression within a learning context has important implications for the successfulness of that context. By detecting such an expression, a learning system may be able to make important statements on (a) how the learner learns, (b) how well the curriculum handles the learning objectives related to the insight, and (c) whether the educators' interventions are successful. This information can be further used by learners directly from their own contemplation and self-regulation. This may generate further moments of insight.

In the second type of insight, the learner may have access to a computational model created by someone but uses his/her own data set to arrive at insights. Alternatively, the learner may have the data set from someone else but creates his/her own model to arrive at insights. Either of these cases belongs to the analysis of moments of insight. As insightful moments occur, they may imply the generation of new competencies, may indicate metacognitive perturbation in the learner, or may indicate a possible new direction of successful curriculum design, amongst other possibilities. A Learning Analytics system can use these moments of insight to make these implications, build new models of learning efficiencies and instructional effectiveness, and advance a deeper understanding of the elements at work in the educational environment. This type of insight analysis is akin to saltation of pebbles in the riverbed, where learners achieve jumps in their comprehension and application of a set of concepts.

Thirdly, with a deeper understanding of the context in which learning is taking place, a Learning Analytics system can attempt to create moments of insight for the learner. Here, the learner creates the data set and creates models to generate new insights. This is akin to conducting experimental or observational studies, where the goal is to answer completely new hypotheses.

Importantly, collection and classification of insights experienced by learners, as part of their learning profiles, will point to a measure of learner engagement. That is, inquisitive students would tend to graduate from insight detection to insight analysis to insight creation, as time progresses.

Also, depending on the level of study in a curriculum, the percentage of occurrences of these three types of insights could be contrasted against the levels of Bloom's taxonomy, yielding a more precise measure of competency growth.

Observations of exposure to different types of insights within a course and observed effort of students in accomplishing each insight could lead to a measure of capacity of learners, on the cognitive front and the metacognitive front.

## *3.2 Deploying Learning Analytics*

Modern high-volume computing, a cornerstone of big data, relies on the dynamic availability of computing power on demand, depending on the requirements at any given moment. The industry has moved to cloud computing for most of these jobs, using distributed networks of processes running on servers to handle jobs dynamically, flexibly, and all while providing a high quality of service to their end users. The high-volume learning traces generated by a Learning Analytics platform has the same requirements, making the same solution inviting. A successful

Learning Analytics platform therefore can be constructed to make best use of cloud resources, so that the system is not overrun or starved for resources at critical moments, such as near examinations or at the beginning of semesters (Benzaken et al. 2013). A Learning Analytics platform should also consider traits of big data, since more often than not volume of the data, variety of the data, arrival patterns of the data, and veracity of the data tend to fall under the big data realms (Bader-Natal and Lotze 2011; Dobre and Xhafa 2013). In particular, traditional databases are known to be poor choices for dealing with large volumes of data needed for big data analytics systems (Agarwal et al. 2013).

The personal ownership of data and models should be explicitly acknowledged. A Learning Analytics platform, ethically designed, must ensure that its information is partible—that is, each individual's data set may be joined or separated from the main database at the desire of its owner. Further, each individual must be granted full control over their data, including the requirement that each use of their data is a wilful, conscious decision on the part of the user (Jensen 2013; Prinsloo and Slade 2015).

### *3.3 Learning Analytics and the Curriculum*

Learning is a key outcome of an educational environment, and the learning outcomes are achieved through curricular design and activities. Learning Analytics offers deeper cross-references and cross-analyses of events within a particular class or course. These can be expanded to curricular analytics, which examines students' learning experiences in the context of the entire curricula. Curricular analytics explores relations between efficiency of student learning with curricular elements such as topics coverage, prerequisite relations amongst topics, learning outcomes, instructor effectiveness, student workload, students' capacity, cultural constraints, and socio-economic–political influences. Curricular analytics also aims to relate the effectiveness of instruction in achieving curricular goals. That is, curricular analytics enables one to detect, analyse, and discover insights concerning the curricular outcomes based on evidences from learner interactions and instructional delivery.

## 4 Analytics in Authentic Learning

Learning Analytics aims to enrich learning experiences as a measurable consequence of moments of insights. Authentic moments of insights, across learning domains, can be targeted and brought to the attention of students. The authenticity of insights can be placed in a pedagogical continuum that has abstraction-oriented pedagogy at one end and reality-oriented pedagogy at the other end. Learning Analytics system can immerse students in the right dosage of authenticity as a balance between students' capacity, curricular learning outcomes, and the instructor's drive.

### 4.1 Abstraction-Oriented Instruction

Abstraction-oriented approaches to instruction offer study activities encompassed in teaching methods that allow for generalizable outcomes. Generalized approaches to study enable students to gain broadly applicable skills. A learner graduating with a suite of generalized skills will be able to triangulate and hone these skills towards context-specific applications in the real world.

A majority of contemporary higher education institutions adopt abstraction-oriented instruction. A variety of pedagogical strategies have been employed in instruction to introduce concepts in a generic manner. In the area of Computer Networks, the types of data transmission have traditionally been introduced without referring to the names of cables that are used for data transmission. In this case, students do not have to even use a cable to test data transmission. Instead, a major curricular goal in Computer Science is to invite students to measure the speed of various data transmission algorithms and find ways to improve the speed. Another major curricular goal in Computer Engineering is to investigate the properties of material used in transmission lines and explore ways to improve the medium of transmission. In both scenarios, traditionally, students are introduced to generic concepts that have been tested and true. Only a handful of institutions offer hands-on lab sessions where students are expected to understand data transmission using real-world cables and real-world equipment that measure transmission speed.

Similarly, curricular goals have targeted storyboard designs containing characters of abstracted personality types without resorting to developing the corresponding storyboard that associates real people to specific personality types. Curricular goals have targeted learning abstract algorithms without requiring students to write one for use in a real-world application. Curricular goals have targeted the writing of a novelette for a course project without having to take it further towards production of a movie based on the novelette. Curricular goals have targeted a study of equations without ever having to apply them in real-world Physics. One could study all about butterflies in a virtual world without ever having to venture into a forest to experience real wild butterflies.

The world of abstracted instruction has, for a good reason, abstracted the viewpoints of curricular goals. This, in turn, implies that students are exposed only to ideas that have been tested and true, ideas that have already been in use in the real world, requiring students to think about the next steps of evolution of these ideas.

The goals of abstracted viewpoints may not suit the learning style or learning capacities of all students. Also, abstracted viewpoints may not be a right pedagogical approach all the time, for all the subject domains, even for students who are conducive to receiving instruction in an abstracted manner.

Abstracted instruction has the benefit of cost-effectiveness in that most of the outcomes can be explored and achieved in a bookish fashion, without resorting to expensive lab equipment. Institutions need not recruit professionals who have practical experiences. Rather, institutions are known to hire instructors who prefer abstracted instruction.

Study activities and assessment activities that are subjected to abstracted viewpoints are said to employ pedagogies that target abstracted instruction. Reading books, social interactions, peer-to-peer reviews, summarizing ideas, simulating tests, and predicting outcomes are example pedagogical strategies that target abstracted viewpoints.

## *4.2 Reality-Oriented Instruction*

Study activities and assessment activities can also be reality-based, immersing study activities in pedagogies that offer virtual, augmented, or even real reality experiences.

Learning about software engineering skills from direct observations and analysis of project managers and teams involved in the development of real software projects is an example of a reality-based pedagogical approach. This allows students to develop specialized approaches to study and gain context-specific skills, in situ. That is, students can be placed in more realistic learning situations, to experience both study activities and assessment activities in-person, or experience them using a virtual reality environment, or interact with them through an augmented reality environment. For instance, using videoconferencing or virtual/augmented reality environments, students can observe professional coding teams work in situ as they incorporate client requests, as they design, as they develop, as they debug, as they test, as they optimize, as they plan deployment, and as they deploy commercial software. That is, rather than studying these steps through books or through lectures, students receive first-hand information about software engineering from real-life projects.

Visits to the museum, student exchange, live laboratories, apprenticeship, workplace connectivity, and virtual experiences of geographically distant content are examples of pedagogical strategies that employ reality-based instruction.

While abstraction-oriented pedagogies enable students to triangulate their skills towards specific applications in the real world, authentic reality-based instruction enables students to generalize and theorize their real-world experiences.

Academic qualifications in Business, Law, Medicine, and Architecture tend to include real-world reality-based instruction as part of the curricula to prepare students before they venture into careers not only because these are impactful professions but also because of the instructional design requirements that found a balance between abstraction and reality.

## *4.3 Learning Analytics as the Backbone of the Abstract-Reality Continuum*

Education is a society altering mechanism. Rather than chasing every new technology or technique available in the market, institutions, or teaching and learning, need to adopt only proven platforms (Miller et al. 2004). Educational technology tools are available to provide abstraction-oriented instruction or reality-based instruction for the topic or concept in question. These tools also allow one to customize the level of immersion in either of the two modes of operation at question —abstraction and reality—allowing learners to learn more independently, more enjoyably, more effectively, more connected with the society, and more connected with the learning environment.

Educators will also have the opportunity to choose between reality-oriented learning experiences and abstracted learning opportunities in their classrooms. That is, educators can choose a well-designed and informed interplay between these two ends of the instructional continuum.

While Learning Analytics does not dictate or advocate any particular orientation of the pedagogy, it does allow one to measure the pedagogy that is appropriate, effective, and efficient for each student. This is possible because Learning Analytics systems are in a position to capture study and assessment activities of students at much finer levels of granularity allowing multiple models on a student's capacity, motivation, cognition, and subject knowledge to be instantiated, continuously, as and when data points are obtained. Such flexibility empowers Learning Analytics tools to infer and recommend a right balance of abstraction and reality-based instruction that fits the needs of each student.

## 5 Conclusion

Learning Analytics, the study of insights-based learning, is becoming increasingly important as institutions target twenty-first-century skills. The incredible amount of information produced by the educational environment, every day, has the potential to assist institutions reach their twenty-first-century goals. However, in contemporary education, for the most part, much of these data go untapped.

Traditional systems are able to interpret data outside of a narrow range of formats, isolating data into silos. Newer systems may be able to bridge the gap across these silos, but they lack the powerful inferencing systems of an analytics engine to make more than simple statements. Proper analytics engines, however, are able to take this ocean of data and draw broad, comprehensive statements from it towards discovery, analyses, and creation of moments of insight for all members of the educational system.

Such analytics engines are also capable of measuring the efficiency with which students learn and determine the impact of instructional design on their study habits. Further, analytics inferences can be drawn to distinguish between the impact of abstraction-oriented pedagogy and the impact of reality-oriented pedagogy, and their respective impact on the study habits and performance improvements of students. These measures can then be used to determine the right amount of balance between the two pedagogies, individualized to meet the required balance for each student. Authentic learning is about exposing real-world problems to students and allowing them to construct real-world solutions. *This chapter contends that the degree to which authentic instruction and authentic learning can be immersed is based on a delicate balance between the abstraction-oriented and reality-based pedagogies, and Learning Analytics has the means to justify, guide, and govern this balance.*

Depending on the content, learning outcomes, and curricular goals, students can be subjected to various degrees of immersion in authentic learning environments. For instance, a law curriculum, for specific topics, could mandate the students to learn from real sessions in court proceedings. While students learn from real court proceedings, certain activities such as interaction and assessment would not be authentic since students cannot intervene in real court proceedings. As such, these activities (e.g. interaction and assessment) will be covered away from the real court scenarios. Thus, from a curricular point of view, a set of topics could be instructed and learned in a mixture of real-world and abstracted environments. But, the activities are quite segregated from each other, where the real-world activities are not in synchronization with the other activities, and all the activities can be conducted in different time frames.

The same curriculum, for specific topics, could expect instructors to expose students to case studies offered through augmented reality technologies. That is, students can still be a part of real court proceedings, but will be allowed to interact with specific objects and interact with people through augmented reality interfaces. For instance, if a section of a statute is mentioned by a lawyer in a real court proceeding, the student observing the proceeding in situ can seek to review highlights of the statute using the augmented reality goggle. That is, sections of the statute, relevant for the arguments being made in the court room, can be made available through the goggle to the students who require them. Students can also share and discuss this immersive experience with fellow students or the instructor, while the real court proceeding is live and ongoing. In this case, the augmented reality technology enables students to combine real-world interactions with virtual interactions; thus, both real-world activities and other activities are situated in the same time frame, overlapping each other. Student can switch between these activities as they see fit.

In yet another example, one can immerse students in simulated case studies where the real-world court sessions can be simulated, where students can take active part in the proceedings. In such role playing scenarios, the degree of immersion can be quite high where the instructional design combines various activities associated with learning.

Depending on the learning outcomes, Learning Analytics systems can offer instructors and students, at any given timeframe, a particular degree of immersion, a particular mixture of interleaved interactions, and a particular level of role play. These learning analytic opportunities facilitate instruction to be as authentic as it needs to be in order to individualize and optimize pathways that help students reach their learning outcomes.

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# Supporting Reflective Lesson Planning Based on Inquiry Learning Analytics for Facilitating Students' Problem Solving Competence Development: The Inspiring Science Education Tools

**Panagiotis Zervas and Demetrios G. Sampson**

**Abstract** Science education is recognized as a top priority for school education reforms worldwide. Inquiry-based teaching strategies are recognized as appropriate for supporting the development of the cognitive processes that cultivate problem solving (PS) competence, a key competence of scientific literacy. A widely used framework for assessing individual students' problem solving competence at large scale is PISA 2012 Problem Solving Framework (PSF). Nevertheless, PISA 2012 PS competence assessment is primarily summative and not connected to the daily school science teaching practice. On the other hand, school accountability and self-improvement requires evidence to relate students' PS competence development to specific design considerations of lesson plans and their corresponding teaching and learning activities used in day-to-day school science inquiry-based teaching practice. Within this context, the scope of this book chapter is to present and discuss a set of tools which aim to support the authoring and delivery of technology-enhanced science education lessons, which follow an adaptation of the 5E model, while incorporating PISA 2012 PSF compatible assessment activities at each inquiry phases. These tools support science teachers in collecting inquiry learning data, namely data from students' activities and students' problem solving competence performance data at each stage of the inquiry process. The further

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analysis of those inquiry learning data can be used for evidence-based reflective lesson planning targeting to better support students' problem solving competence development through inquiry-based teaching.

**Keywords** School education · STEM education · Inquiry-based learning · Problem solving competence · PISA 2012 problem solving framework · Authoring tool · Delivery tool · Reflective lesson planning · Inquiry learning analytics

## 1 Introduction

Authentic learning has been recognized as a key challenge for twenty-first century school education (Lombardi 1997). Facilitating authentic learning as well as assessing learning through authentic activities has been identified as a core issue for technology-supported school education, as technologies are expected to facilitate authentic, real-world learning experience integrated in classroom environments (Herrington and Oliver 2000; Williams and Penny 2011; Santos et al. 2015). In particular, innovations in science school education have long been associated with classroom technologies that can facilitate real-life, complex problem solving competences and open-ended inquiry (Edelson 1997).

Science education is recognized as a top priority for school education reforms worldwide, and thus, a key challenge for technology-supported and technology-enabled school education innovations (Johnson et al. 2012). Developing scientific literacy in compulsory school education anticipates preparing students to: (a) be able to understand the nature and development of scientific knowledge; (b) generate and evaluate scientific evidence and explanations; and (c) participate productively in scientific practices and discourse (McFarlane 2013; Albert 2009). Thus, there is a need for engaging students in student-centered and active learning practices such as inquiry-based learning (Gormally et al. 2009). *Inquiry* is the process in which students are engaged in scientifically oriented questions, perform active experimentation, formulate explanations from evidence, evaluate their explanations in light of alternative explanations, and communicate and justify their proposed explanations (National Research Council 2000). As a result, inquiry-based teaching models are recognized as appropriate teaching strategies to support deep understanding of domain specific conceptual knowledge and prepare students to apply this knowledge in novel real-life situations (OECD 2013a). Moreover, inquiry-based teaching strategies are recognized as appropriate to support self-regulated learning and meta-cognition, as well as to support the development of the cognitive processes that cultivate problem solving (PS) competence (Saunders-Stewart et al. 2012; Prince and Felder 2006).

Problem solving competence is a core objective for most compulsory education (K-12) curricula and a critical competence for higher education studies, professional career readiness and effective citizenship (Greiff et al. 2014). The acquisition of high levels of problem solving competence provides students with the capacity to think critically and creatively in solving complex real-life problems (Ifenthaler et al. 2010; Lesh and Zawojewski 2007). Yet, both developing and assessing problem solving competences as part of school education remains an open challenge (Adamson and Darling-Hammond 2015; Gibson and Webb 2015; Webb and Gibson 2015; Williams and Newhouse 2013).

A widely accepted framework for assessing individual students' problem solving competence at large scale is PISA 2012 Problem Solving Framework (PSF), which has been developed by the Organization for Economic Cooperation and Development (OECD) to address the need for cross-nationally comparable evidence for student performance on problem solving (OECD 2013a). However, PISA 2012 PS competence assessment is primarily summative and not directly connected from the daily school science teaching practice. On the other hand, school accountability and self-improvement requires evidence to relate students' problem solving competence proficiency level development to specific design considerations of lesson plans and their corresponding teaching and learning activities performed in day-to-day school science inquiry-based teaching practice. Thus, the thesis of our work is that by incorporating appropriate PISA 2012 PSF compatible assessment activities within the phases of an inquiry-based teaching strategy, we can collect useful rich inquiry learning data, from students' activities and students' problem solving competence performance data at each stage of the inquiry process, which can be, then, used by teachers to reflect on and accordingly adapt their lesson plans toward better supporting students' performance on problem solving competence.

Within this context, the scope of this book chapter is to present the design considerations and the implementation of a set of tools which aim to support the authoring and delivery of technology-enhanced science education lessons that follow an inquiry-based teaching strategy, in particular, an adaptation of the 5E model, while incorporating appropriate PISA 2012 PSF compatible assessment activities within each phases of the inquiry teaching model. The further analysis of those inquiry learning data can be used for evidence-based reflective lesson planning based on inquiry learning analytics, targeting to better support students' PS competence development through inquiry-based teaching. The tools described in this book chapter have been developed in the framework of a major European Initiative, namely the Inspiring Science Education (ISE) Project.[1]

The chapter is structured as follows. Following this introduction, Sect. 2 discusses the benefits of adopting inquiry-based science teaching strategies as the means to develop scientific literacy at school education, with emphasis to cultivate problem solving competence. Moreover, this section presents the problem solving framework that is used by PISA 2012 toward modeling the problem solving process and it highlights our previous work reported in Zervas et al. (2015) on how assessment activities following this framework can be incorporated in the various phases of an inquiry-based teaching model. Section 3 presents the design considerations and the implementation of the ISE Authoring Tool and ISE Delivery Tool,

[1]http://www.inspiring-science-education.org/).

which are used by science teachers to design and delivery inquiry-based lessons enhanced with problem solving assessment activities compatible with PISA 2012 PSF. Finally, main conclusions and ideas for future work are discussed.

## 2 Background

### *2.1 Inquiry-Based School Science Education*

Science education plays a critical role in societies' competitiveness and economic future (Lewis and Kelly 2014). It should be clarified that in the context of this book chapter, when referring to Science at large, this includes natural sciences (physics, biology, chemistry, astronomy, geology, etc.), technology (including computer science) and mathematics also referred to as STEM (science, technology, engineering and mathematics).

Science education is essential for students of all backgrounds, talents, interests and abilities. More specifically, engaging students in the process of understanding science as part of their daily lives can provide them with a great foundation for success in their lives. Thus, it is essential for students to cultivate competences that develop their scientific literacy, which is defined as: "*the ability to engage with science-related issues and with the ideas of science, as a reflective citizen*" (OECD 2013b).

Inquiry-based learning is commonly recognized as an appropriate strategy for developing scientific literacy in compulsory school education (Gormally et al. 2009). Inquiry-based learning is typically organized into inquiry phases that together form an inquiry cycle (Pedaste et al. 2015). A widely used inquiry learning model is the 5E model, which lists five inquiry phases, namely engagement, exploration, explanation, elaboration and evaluation (Bybee et al. 2006). In our work, we have adapted the 5E model by considering also the main inquiry processes identified by Bell et al. (2010). More specifically, the following inquiry phases have been adopted:

- **Orienting and Asking Questions**: This phase involves the presentation of the problem to be engaged with and aims to provoke curiosity.
- **Hypothesis Generation and Design**: This phase involves the formulation of initial hypotheses from the students based on their own reason and current understanding of the matter at hand.
- **Planning and Investigation**: This phase is related to the collection, analysis and organization of the research/experimentation processes and the related tools/resources that will facilitate these. This can be discovered by the students or provided by the science teacher.
- **Analysis and Interpretation**: During this phase, the learners engage in experimentations following the processes outlined in the previous phase and utilizing the tools/resources selected in that phase.

- **Conclusion and Evaluation**: This phase includes reflective analysis of the learners initial hypotheses based on the newly acquired knowledge and experience. Moreover, it aims to assist learners in gaining a more holistic view of the scenario problem.

Several studies have demonstrated that inquiry-based learning: (a) leads to better acquisition of domain specific conceptual knowledge (Hwang et al. 2013; Minner et al. 2010), (b) has a significant positive influence on students' motivation (Tuan et al. 2005), (c) leads to increased students' engagement (Tsai and Tuan 2006) and (d) has a significant positive influence on students' attitudes toward science (Koksal and Berberoglu 2014).

Moreover, inquiry-based learning is recognized as appropriate to support self-regulated learning and meta-cognition, as well as to support development of the cognitive process that cultivate PS competence (Saunders-Stewart et al. 2012; Prince and Felder 2006). Thus, to be able to measure (among others) the effectiveness of inquiry-based learning, efficient assessment of students' performance on PS competence is needed.

## *2.2 The PISA 2012 Problem Solving Framework and Its Mapping to the Inquiry Cycle Phases*

Problem solving competence is defined as: "*an individual's capacity to engage in cognitive processing to understand and resolve problem situations where a method of solution is not immediately obvious. It includes the willingness to engage with such situations in order to achieve one's potential as a constructive and reflective citizen*" (OECD 2013a). The Programme for International Student Assessment (PISA) has proposed a widely accepted framework for assessing individual students' problem solving competence at large scale, namely PISA 2012 Problem Solving Framework (PSF). The PISA 2012 PSF defines four (4) different steps for solving a complex problem, namely (OECD 2013a), as follows:

- **Exploring and understanding the problem**: this step includes (a) exploring the problem situation (observing, interacting, searching for information and limitations) and (b) understanding the given information and the information discovered while interacting with the problem situation.
- **Representing and formulating the problem**: this step includes (a) select relevant information, mentally organize and integrate with relevant prior knowledge and (b) shifting between representations or formulating hypotheses by identifying the relevant factors.
- **Planning and executing the strategy for solving the problem**: this step includes: (a) clarifying the overall goal and setting sub-goals and (b) devising a plan or strategy to reach the goal state. After that, in the executing phase, the plan will be carried out.

- **Monitoring and reflecting the solution**: this step includes: (a) monitor the progress toward reaching the goal at each stage including checking intermediate and final results, detecting unexpected events and (b) reflect on solutions from different perspectives and critically evaluate assumptions and alternative solutions.

The range of problem solving assessment tasks included in the PISA 2012 PSF allows for describing six levels of problem solving proficiency that can be grouped into three main categories, namely (OECD 2014):

- **High Performers (Level 5 and Level 6)**: students at this category can: (a) develop complete, coherent mental models of different situations and (b) find an answer through target exploration and a methodical execution of multi-step plans.
- **Moderate Performers (Level 3 and Level 4)**: students at this category can: (a) control moderately complex devices, but not always efficiently and (b) handle multiple conditions or interrelated features by controlling different variables.
- **Low Performers (Level 1 and Level 2)**: students at this category can: (a) answer whether a single, specific constrain has to be taken into account and (b) partially describe the behavior of a simple, everyday topic.

To this end, in order to be able to assess students' problem solving competence following the PISA 2012 PSF within the context of inquiry-based learning, we have proposed to incorporate appropriate assessment tasks in various phases of the inquiry cycle (Zervas et al. 2015). Table 1 presents the mapping between the aforementioned PISA 2012 problem solving steps and the adopted inquiry cycle phases. Moreover, this mapping is complemented with proposed guidelines for developing assessment tasks toward assessing each of the PISA 2012 problem solving steps at the different phases of the inquiry cycle.

Following the mapping of Table 1, in the next section we present the design considerations and the implementation of a set of tools which aim to support the authoring and delivery of technology-enhanced science education lessons that follow the inquiry cycle (as specified in Sect. 2.1) and incorporate appropriate assessment tasks compatible with PISA 2012 PSF within the various phases of the inquiry cycle.

## 3 The Inspiring Science Education Tools

The set of tools that will be presented in this section has been developed in the framework of a major European Initiative, namely the Inspiring Science Education (ISE) Project.[2] The ISE project aims to develop a web-based portal for European school science teachers toward allowing access to: (a) a wide number of science educational resources from a federated network of web-based repositories, (b) a

[2]http://www.inspiring-science-education.org/.

**Table 1** Mapping between PISA 2012 problem solving steps and inquiry cycle phases (Zervas et al. 2015)

| Inquiry phases | PISA 2012 problem solving steps | Guidelines for preparing assessment tasks |
|---|---|---|
| Orienting and asking questions | Exploring and understanding the problem | 1. Deal with the representation of the problem<br>2. Deal with relevant information to understand the problem<br>3. Deal with different levels of understanding of subject domain knowledge |
| Hypothesis generation and design | Representing and formulating the problem | 1. Deal with the exploration of correlations and dependencies<br>2. Deal with a precise description of the focused problem |
| Planning and investigation | Planning and executing the strategy for solving the problem | 1. Deal with the correct strategies of experimentation<br>2. Deal with strategies of variable control<br>3. Deal with strategies for data analysis |
| Analysis and interpretation | Monitoring and reflecting the solution | 1. Deal with application or transfer of problem tasks<br>2. Deal with possible sources of experimental errors<br>3. Deal with enhancement of experimental setting |
| Conclusion and evaluation | – | – |

web-based repository of educational tools for supporting inquiry-based science education and (c) online science teachers' communities and accompanying community tools.

Furthermore, the ISE Project has designed and implemented two tools, namely the ISE Authoring Tool and the ISE Delivery Tool, which aim to support the authoring and delivery of technology-enhanced science education lessons that follow an inquiry-based teaching strategy, in particular, an adaptation of the 5E model, while incorporating appropriate PISA 2012 PSF compatible assessment activities within each phases of the inquiry teaching model. The further analysis of those inquiry learning data can be used for evidence-based reflective lesson planning based on inquiry learning analytics, targeting to better support students' PS competence development through inquiry-based teaching. In the subsequent sections, we describe both tools in more details.

## *3.1 The Inspiring Science Education Authoring Tool*

The scope of this section is to present the design considerations and the technical implementation of the ISE Authoring Tool, which can be used by science teachers to design technology-enhanced inquiry-based lessons enhanced with problem solving assessment tasks, compatible with PISA 2012 PSF.

### 3.1.1 Design Considerations

In order to be able to develop the ISE Authoring Tool, we defined a set of deign considerations that have been derived from the need to: (a) support authoring of technology-enhanced science education lessons based on the inquiry cycle (as presented in Sect. 2.1), (b) support authoring of assessment tasks based on the PISA 2012 PSF (as presented in Sect. 2.2), (c) support associating evidence of students' performance on PS competence and subject domain knowledge with different versions of technology-enhanced inquiry-based lessons, (d) integrate the ISE Authoring Tool with the ISE Portal, so as to enable access to the available digital educational resources and tools as well as to store (along with educational metadata) the developed technology-enhanced inquiry-based lessons.

To this end, the following design considerations have been defined:

- **A-DC1**: Science teachers should be able to develop technology-enhanced science education lessons following the inquiry cycle (as presented in Sect. 2.1). This is needed in order to guide science teachers to structure their lessons following the principles of the inquiry cycle.
- **A-DC2**: Each phase of the inquiry cycle should include a set of inquiry activities. Each inquiry activity should include:
  - **A-DC2.1**: Digital educational resources of different technical formats, namely text, images and videos. This is important for enriching inquiry activities with different types of digital educational resources.
  - **A-DC2.2**: External digital educational resources stored in the ISE Portal. This is important for reusing existing digital educational resources from the ISE Portal.
  - **A-DC2.3**: External digital educational tools stored in the ISE Portal's Tools Repository. This is needed in order to enrich inquiry activities with educational tools that supports the main characteristics of the inquiry process hypothesis generation, active investigation, formulate explanations, etc.
  - **A-DC2.4**: Guidelines/notes for the science teacher to implement the inquiry activity. This is essential for guiding science teachers when they implement an inquiry activity in their classroom.
  - **A-DC2.5**: Assessment tasks to assess students' subject domain knowledge and provide feedback. This is important for assessing students' understanding on specific aspects and remedying any misconceptions through the provided feedback.
- **A-DC3**: Science teachers should be able to add at the end of each inquiry phase appropriately designed assessment tasks, so as to allow for the assessment of the PISA 2012 problem solving steps (as presented in Sect. 2.2). This is essential

for preparing the collection of students' PS competence performance data in a formative manner, namely at each phase of the inquiry cycle.

- **A-DC4**: Science teachers should be able to store with educational metadata their technology-enhanced science education lessons to the ISE Portal, so as to render them searchable from other science teachers. This is important for enabling other science teachers to reuse existing inquiry-based lessons.
- **A-DC5**: Science teachers should be able to clone and adapt technology-enhanced science education lessons developed by other science teachers. This means that science teachers should be able to both copy an existing technology-enhanced science education lesson developed by another science teacher (clone) and based on this, incorporate potential changes for addressing their needs (adapt). This is important in order to support novice science teachers to get inspired to develop their own inquiry-based lessons by following other more experienced science teachers' work.
- **A-DC6**: Science teachers should be able to have access to a dashboard of the different versions of their developed technology-enhanced science education lessons associated with the corresponding students' performance on PS competence and subject domain knowledge. This is essential for collecting useful inquiry learning data to further analyze for reflective inquiry-based lesson planning targeting students' problem solving competence development.

### 3.1.2 Technical Implementation

The design considerations presented in Sect. 3.1.1 have been translated in functionalities for the ISE Authoring Tool. These functionalities are summarized below:

**Develop an Inquiry-based Lesson (*addressing A-DC1*)**: this functionality allows science teachers to develop an inquiry-based lesson by following the inquiry cycle (as presented in Sect. 2.1). More specifically (as depicted in Fig. 1) the different phases of the inquiry cycle are presented as different tabs where the science teacher can select them and develop inquiry activities for his/her inquiry-based lesson.

**Develop an Inquiry Activity (*addressing A-DC2*)**: this functionality allows science teachers to develop inquiry activities for the different inquiry phases of a lesson. Each inquiry activity can include a set of different elements, namely:

- Digital educational resources of any type such as text, images and videos (*addressing A-DC2.1*). This is supported via a rich-text editor component that has been integrated to the ISE Authoring Tool.
- Digital educational resources stored in the ISE Portal (*addressing A-DC2.2*). This is supported by a search mechanism integrated to the ISE Authoring Tool, which enables searching with educational metadata (following the IEEE LOM standard (IEEE LTSC 2005)) of the educational resources stored in the ISE Portal.

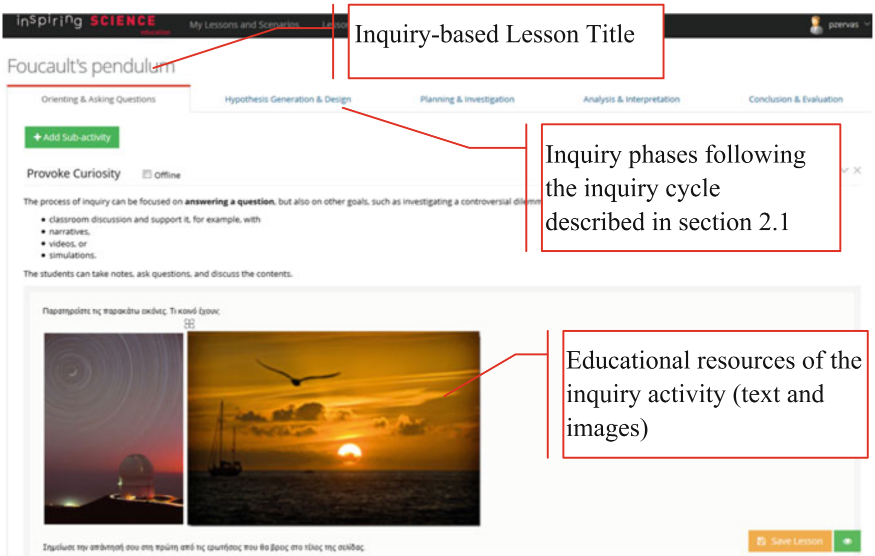


**Fig. 1** ISE Authoring Tool—the process of developing an inquiry-based lesson

- Digital educational tools stored in the ISE Portal's Tools Repository (*addressing A-DC2.3*). This is supported by a search mechanism integrated to the ISE Authoring Tool, which enables searching with educational metadata to the digital educational tools stored in the ISE Portal Tools Repository.
- Guidelines/notes for the science teacher to implement the inquiry activity during delivery in the classroom (*addressing A-DC2.4*). This is supported via a rich-text editor component that has been integrated to the ISE Authoring Tool.
- Assessment tasks to assess students' subject domain knowledge and provide feedback (*addressing A-DC2.5*). This is supported by a dynamically created multiple choice question component integrated to the ISE Authoring Tool, which enables science teachers to create multiple choice questions and indicate the correct answer, as well as to add textual feedback to be presented to the students when they select an answer.

**Assess Problem Solving Competence (*addressing A-DC3*)**: this functionality allows science teachers to add multiple choice questions at the end of the inquiry phases via a dedicated web form, so as to assess students' problem solving competence (as depicted in Fig. 2). The answers to the questions are mapped to the three (3) proficiency levels of problem solving identified by PISA PSF, namely low performers, moderate performers and high performers (as described in Sect. 2.2).

**Store to the ISE Portal (*addressing A-DC4*)**: this functionality allows science teachers to characterize an inquiry-based lesson with educational metadata following the IEEE LOM standard (IEEE LTSC 2005) and store it to the ISE Portal (as depicted in Fig. 3). This is implemented through a step by step metadata wizard,

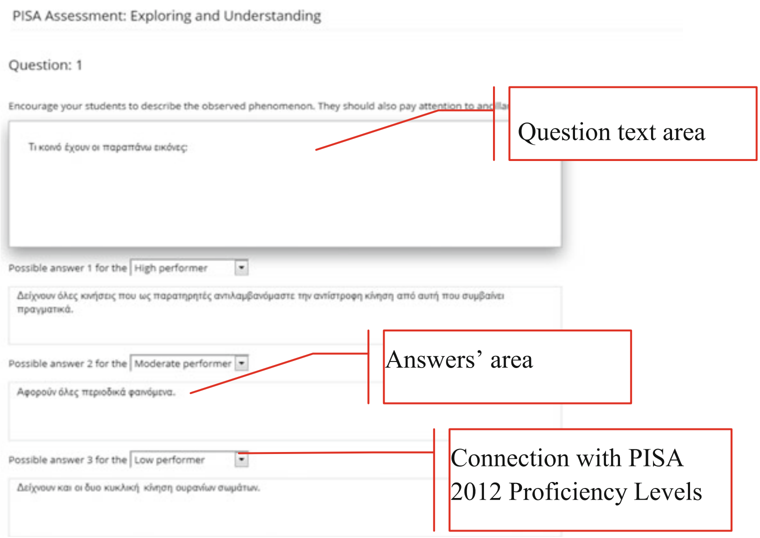


**Fig. 2** ISE Authoring Tool—the process of authoring problem solving questions

which enables science teacher to easily characterize his/her inquiry-based lesson with educational metadata, so as to be stored to the ISE Portal.

**Clone and Adapt an Inquiry-Based Lesson (*addressing A-DC5*)**: this functionality allows science teachers to search inquiry-based lessons developed by other science teachers, clone them and adapt them to address their needs. This is implemented by enabling via the ISE Authoring Tool the capability to provide access to inquiry-based lessons developed by other science teachers (if this is allowed by the author). When a science teacher finds an inquiry-based lesson, he/she can clone it to his/her profile and further change/adapt it without affecting the original inquiry-based lesson.

**Dashboard of Previously Delivered Inquiry-Based Lessons (*addressing A-DC6*)**: this functionality allows science teachers to have access to the different versions of their inquiry-based lessons, which have been already delivered to their students and they include aggregated data of students' performance on problem solving competence and subject domain knowledge (as depicted in Fig. 4).

## 3.2 *The Inspiring Science Education Delivery Tool*

The scope of this section is to present the design considerations and the technical implementation of the ISE Delivery Tool, which can be used by science teachers to deliver classroom-based inquiry lessons enhanced with problem solving assessment tasks compatible with PISA 2012 PSF and collect useful inquiry learning data for performing reflective lesson planning.

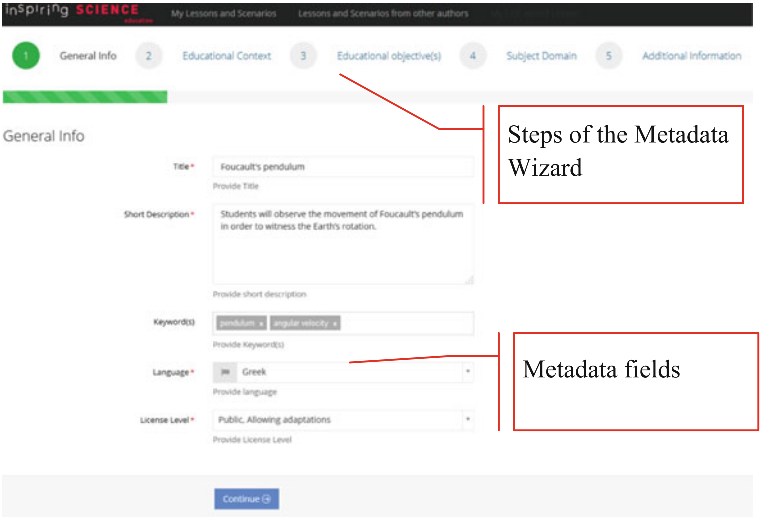


**Fig. 3** ISE Authoring Tool—educational metadata wizard

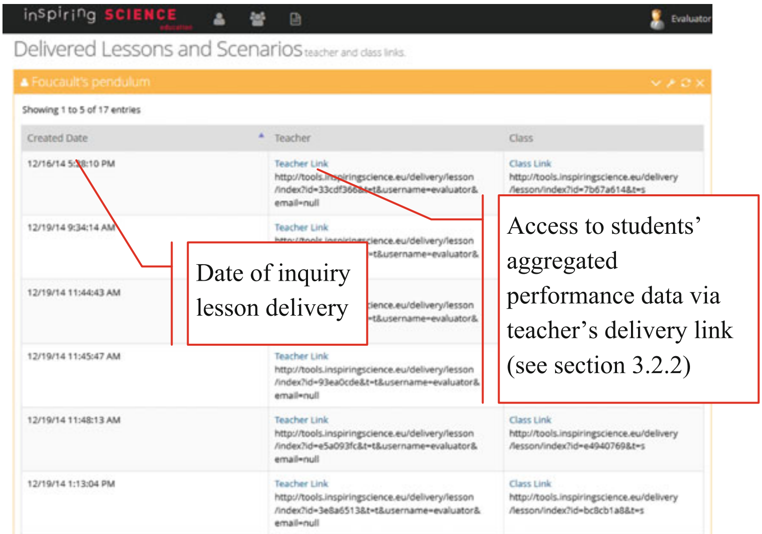


**Fig. 4** ISE Authoring Tool—dashboard of previously delivered inquiry-based lessons

### 3.2.1 Design Considerations

The same procedure with the ISE Authoring Tool has been also followed for the ISE Delivery Tool. More specifically, a set of design considerations has been defined based on the need to: (a) access the ISE Delivery Tool from the ISE

Authoring Tool, (b) enroll students to technology-enhanced science education lessons that follow the inquiry cycle (as presented in Sect. 2.1), (c) assess students based on the PISA 2012 PSF (as presented in Sect. 2.2) at each phase of the inquiry cycle, (d) enable science teachers to monitor their students' proficiency levels in terms of PISA 2012 PSF as well as subject domain knowledge at each phase of the inquiry cycle and (e) enable cross-device access and interface personalization for different accessibility preferences.

To this end, the following design considerations have been defined:

- **D-DC1**: Science teachers and students should be able to access the ISE Delivery Tool via unique web links produced by the ISE Authoring Tool for each lesson to be delivered. This is important for simplifying access during classroom runs.
- **D-DC2**: Students should be able to enroll in science education lessons and to execute the different phases in a fixed order, or "lockstep" fashion. The lockstep procedure means that students will not be able to answer again the PISA 2012 PSF compatible problem solving questions at the end of an inquiry phase when moved to the next one (OECD 2013a). This is important for ensuring compatibility with PISA 2012 PSF. Moreover, considering the students' age range, data privacy issues should be considered by utilizing pseudo-login capabilities.
- **D-DC3**: Students should be able to see at the end of the lesson, data about their performance on subject domain knowledge questions replies, as well as how their performance is compared with the overall class performance. This is essential for facilitating students' self-regulation and personal improvement.
- **D-DC4**: Science teachers should be able to enroll in science education lessons along with their students and they should be able to see an augmented view of the lesson including: (a) notes/guidelines about how to execute specific inquiry activities and (b) the correct answers to PISA 2012 PSF compatible problem solving and knowledge questions. This is important for facilitating science teachers in their classroom runs.
- **D-DC5**: Science teachers should be able to monitor (a) the students enrolled in their technology-enhanced science education lessons (DC5.1), (b) students' PISA 2012 PSF compatible proficiency levels on problem solving competence assessment (DC5.2), (c) students' performance on subject domain knowledge assessment (DC5.3) and (d) students' time spent per inquiry phase (DC5.4). This is essential for supporting reflective lesson planning based on the inquiry learning data gathered by monitoring students' performance.
- **D-DC6**: Science teachers should be able to pause and restart a science education lesson at a later time. This is important for handling time constraints, which might hinder the completion of a lesson
- **D-DC7**: Science teachers and students should be able to access a science education lesson from different devices (desktop or mobile devices) (DC7.1) and personalize the interface according to their accessibility preferences (DC7.2). This is essential for supporting the widespread use of the tool via different devices and by different students' groups.

### 3.2.2 Technical Implementation

The design considerations presented in Sect. 3.2.1 have been translated in functionalities of the ISE Delivery Tool. These functionalities are summarized below:

**Access the ISE Delivery Tool (*addressing D-DC1*)**: This functionality allows science teachers and students to access an inquiry-based lesson via the ISE Delivery Tool. This is achieved via two unique web links that are automatically generated by the science teacher via the ISE Authoring Tool. These links provide access to an inquiry-based lesson to the science teacher (via teacher's link) and to the students (via class link), as depicted in Fig. 5.

**Student Enrollment and Assessment (*addressing D-DC2*)**: This functionality allows students to enroll to an inquiry-based lesson and execute it by following the phases of the inquiry cycle (as presented in Sect. 2.1) and by answering to the different types of assessment questions (namely subject domain and problem solving related questions) of the inquiry-based lesson. This is achieved by requiring from the students to enter a nickname and a passphrase, so as to enroll to the lesson (as depicted in Fig. 6). This is important for ensuring easy login and data privacy of students' personal data. Moreover, after enrollment the student can execute the inquiry-based lesson by interacting with its educational resources and educational tools and answer to the subject domain knowledge and problem solving questions (as depicted in Fig. 6). It should be mentioned that a when student is moved to a next phase the problem solving questions of the previous phase cannot be answered again. This ensures compatibility with PISA 2012 PSF.

**Student Performance (*addressing D-DC3*)**: This functionality allows students to be informed about their performance on subject domain knowledge questions answered during the execution of the inquiry-based lesson. This is achieved by presenting to the students at the end of the inquiry-based lesson with a summative dashboard including their correct replies and the time spent per inquiry phase and for the entire inquiry-based lesson. Moreover, the student performance is compared with the average performance of the class (as depicted in Fig. 7).

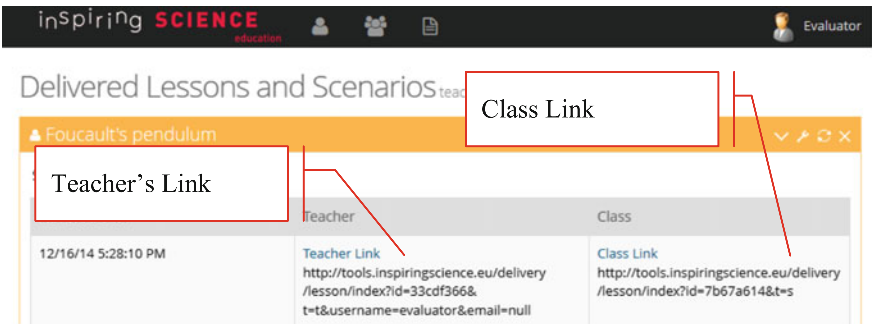


**Fig. 5** ISE Delivery Tool—teacher's and class link


**Fig. 6** ISE Delivery Tool—student login (class link)

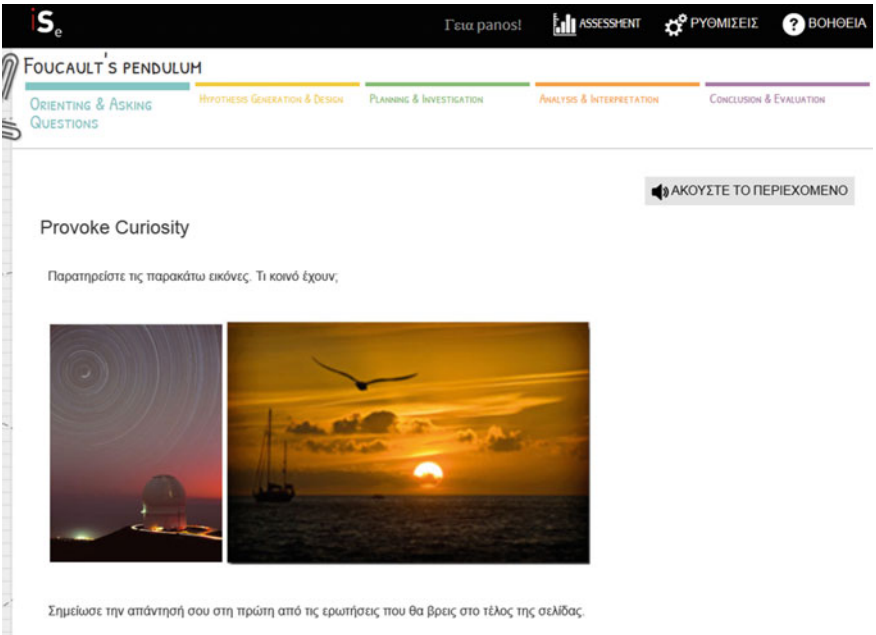


**Fig. 7** ISE Delivery Tool—student's view of an inquiry-based lesson

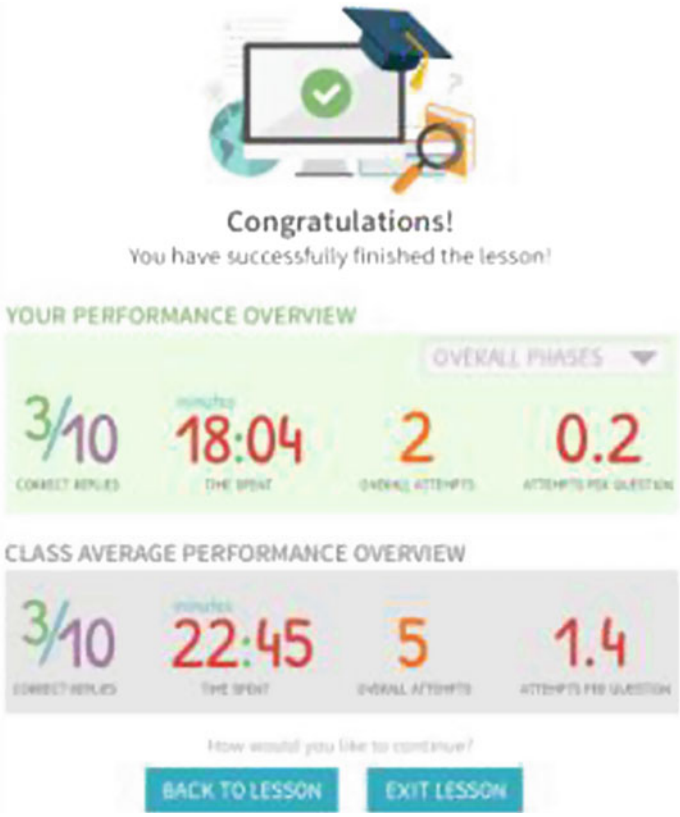


**Fig. 8** ISE Delivery Tool—student's performance dashboard

**Teacher Enrollment (*addressing D-DC4*)**: This functionality allows science teachers to enroll to an inquiry-based lesson via teacher's link (as depicted in Fig. 8), and they can view the educational resources, educational tools and assessment questions that are presented to the students. Moreover, the science teachers are able to see an augmented view of the inquiry-based lesson including notes/guidelines to execute each inquiry activity (as depicted in Fig. 9), as well as the correct answers to the subject domain knowledge questions and the mapping to the PISA 2012 proficiency levels for the problem solving questions.

**Students' Monitoring by the Teacher (*addressing D-DC5*)**: This functionality allows science teachers to monitor the status of their students in terms of their problem solving proficiency level at each inquiry phase and their correct answers to the subject domain knowledge questions. Moreover, they are able to monitor students' time spent per inquiry phase. This is achieved via appropriately designed dashboards that are presented to the science teacher (as depicted in Figs. 10, 11 and 12)

**Pause and Restart Lesson (*addressing D-DC6*)**: This functionality allows science teachers to pause an inquiry-based lesson at a specific inquiry phase and


Fig. 9 ISE Delivery Tool—teacher login (teacher's link)

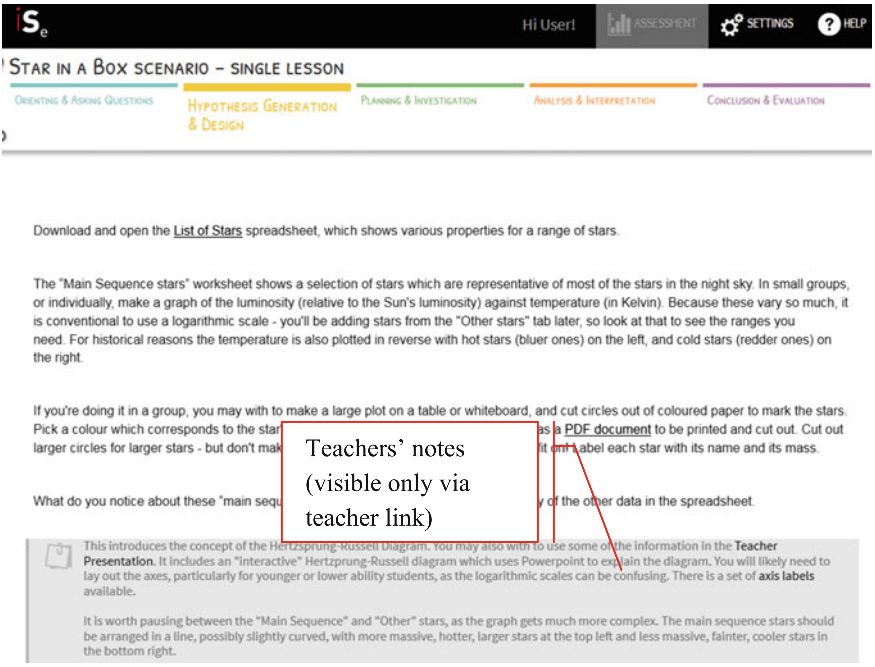


Fig. 10 ISE Delivery Tool—teacher's view

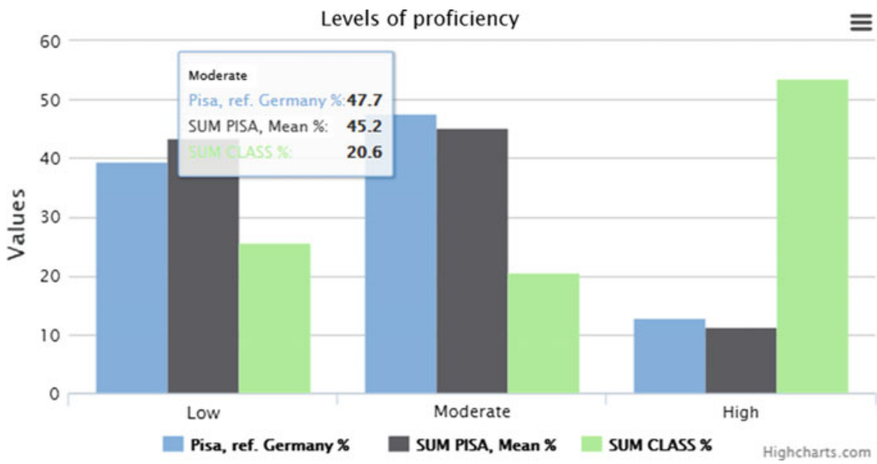


**Fig. 11** ISE Delivery Tool—students' proficiency levels

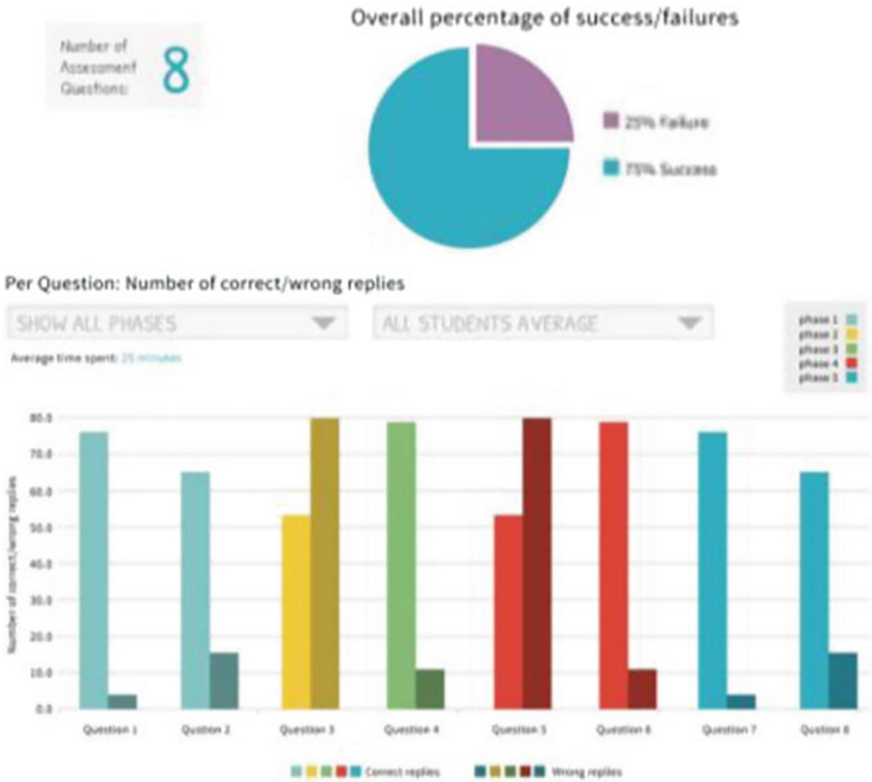


**Fig. 12** ISE Delivery Tool: student's replies to subject domain knowledge questions

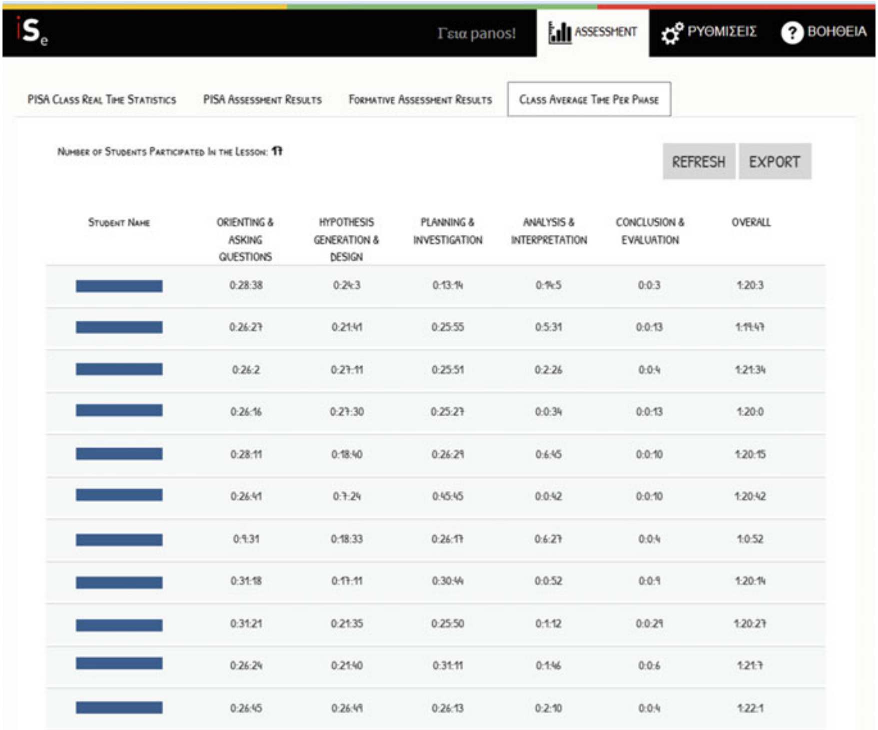


**Fig. 13** ISE Delivery Tool—time spent per inquiry phase

restart it at a later time. This is achieved via a dedicated button presented via the teacher link. When an inquiry-based lesson is paused, new students are not able to login. This functionality enables science teachers to execute parts of an inquiry-based lesson in different time sessions (Fig. 13).

**Cross-Devices Compatibility and Accessibility Features (*addressing D-DC7*)**: The functionality allows end-users of the ISE Delivery Tool (namely students and science teachers) to access it via different devices. This is implemented by utilizing a responsive design framework, namely the twitter bootstrap,[3] which facilitates the same user experience across devices when science teachers and students access the ISE Delivery Tool. Moreover, the ISE Delivery Tool has been developed by incorporating accessibility features including widgets that can enables end-users to change: (a) the text size and style, (b) the contrast, (c) the line spacing and (d) between different layouts (including bigger links and buttons). These features facilitate students with physical disabilities to access and use the ISE Delivery Tool (Figs. 14 and 15).

[3] http://getbootstrap.com/.


**Fig. 14** ISE Delivery Tool—responsive behavior (the navigation bar with the inquiry phases is transferred to the *left* side)

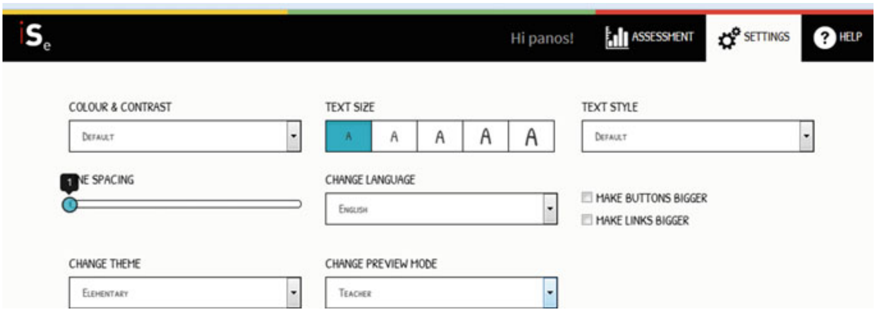


**Fig. 15** ISE Delivery Tool—accessibility features

## 4 Conclusions and Future Work

Facilitating teachers in evidence-based reflective lesson planning is an emerging research field, which can benefit from tools that allow teachers to collect data and monitor students' performance during the delivery of their lessons, so as to inform their decisions when they are redesigning their lesson plans for future delivery (McKenney and Mor 2015; Persico and Pozzi 2015). Within this research agenda, this book chapter initially discussed the need for relating students' problem solving proficiency levels to specific educational design considerations of lesson plans used in day-to-day school science inquiry-based teaching practice, so as to improve lesson planning that supports students problem solving competence development. Toward addressing this need, we claimed that by incorporating appropriate PISA 2012 PSF compatible assessment activities within the phases of an inquiry-based teaching strategy, we can collect useful rich inquiry learning data, from students' activities and students' PS competence performance data at each stage of the inquiry process. These data can be then used by teachers to reflect on and accordingly adapt their lesson plans toward better supporting students' performance on PS competence. As a result, we presented the design and technical implementation of two tools which aim to support the authoring and delivery of technology-enhanced science education lessons that follow an adaptation of the 5E model, while incorporating appropriate PISA 2012 PSF compatible assessment activities within each of its phases.

Future work in this agenda involves two main action lines. First, the inquiry learning data that are being collected during lessons' delivery can be enriched by incorporating data from the students' interactions with inquiry learning and assessment activities. These data can be exploited toward constructing more accurate representations of students' PS competence profile as it dynamically develops during the inquiry cycle. Second, a recommender system can be developed that can provide recommendations to science teachers for reflective lesson planning based on the inquiry learning data collected during previously delivered lessons.

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# Case Studies of Augmented Reality Applications for Authentic Learning

**Su Cai**

**Abstract** The advancement of Augmented Reality technology is having a great influence on the design of learning activities in schools. In this chapter, a serial of simulation cases based on 3D Augmented Reality (AR) environments are presented, including probability learning in mathematics, convex imaging and magnetic field learning in physics, inquiry-based microparticles interactive presentation in chemistry and EFL children's vocabulary studying in language learning, etc. By AR technology, the camera detects the presetting markers which will later generate 3D virtual objects, interposing the virtual objects on the real scene to produce a blended environment. Experimental results show that in an AR-based authentic learning environment, students adopt a natural interactive method and enjoy the same experience as in real environments due to the abandonment of mouse and keyboard devices. It facilitates an innovative and fascinating learning mode which eliminates isolated feelings in learning. Furthermore, the AR-based learning environment is able to interpose objects which are inaccessible in real life due to high expenses, safety consideration or other factors in real-world settings.

**Keywords** Augmented Reality · Authentic learning · Natural interaction

## 1 Introduction

Augmented Reality (AR) is a variation or extension of virtual environments. AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world (Azuma 1997). Therefore, AR supplements reality,

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rather than completely replaces it. Traditional 3D virtual environments give people an isolated feeling in their interactive experience. However, the scenarios based on AR technology provide opportunities for more authentic learning with diverse learning types. Ideally, AR would appear to the user that the virtual and real objects coexist in the same space, in which obstacles between learners and information are eliminated to some extent; teachers and students interact with learning objects as generally as natural. AR displays abstract knowledge in front of the learners. Students can simply drag, drop, grab, flip and perform other operations to interact with virtual learning objects, which make up the gaps of interaction shortcomings in current remote video teaching system.

The main point of authentic learning is to let students encounter and master situations that resemble real life (Cronin 1993). Some researchers assert that emerging technologies are uniquely capable of enabling inquiry-based environments by creating "authentic" science learning environments, and perhaps more importantly, by engaging students in scientific discovery (Chang et al. 2010; O'Connor 2016; San Chee 2014). The ability of AR technology should be considered to engage students and generate an environment for authentic scientific inquiry and discovery.

With the rapid development of AR technology, authentic learning environment by the integration of AR into disciplinary teaching has emerged to a significant extent and been increasingly used in the field of education (Wu et al. 2013). The presentation of AR, based on real-world scenes and enhanced by virtual data, provides a more intuitive and natural way to teach and interact with information, and creates a powerful space for exploration.

The rest of this chapter is organized as follows: Sect. 2 will discuss recent literature about AR for authentic learning in education. Several case studies will then be illustrated in Sect. 3. We conclude with a short summary and predict five trends of AR learning environment in Sect. 4.

## 2 Related Works

Generally, VR/AR is most applicable in the following two instructional situations: (1) when the phenomenon cannot be simulated in reality (e.g., if it is too small or too large), such as the solar system in "the book of the futures" (Cai et al. 2012) and (2) when real experiments are dangerous or have practical concerns (Cai et al. 2013; Cai et al. 2014; Chang et al. 2013a). For example, Cai et al. (2013) used a virtual lit candle in a real classroom for the convex imaging experiment to avoid the risk of fire. Chang et al. (2013a) designed an experiment to examine student's learning behaviors under the nuclear radiation pollution environment near the 1st Fukushima Daiichi Nuclear Power Plant in Japan after the 3.11 earthquake. Cai et al. (2014) targeted "the composition of substances" segment of junior high school chemistry classes and further involved the design and development of a set of inquiry-based Augmented Reality learning tools. They concluded that the AR tool has a significant supplemental learning effect as a computer-assisted learning tool and is more effective for low-achieving students than high-achieving ones. Students generally have positive attitudes toward AR tools, and students' learning attitudes are positively correlated with their evaluation of the software.

Despite evidences that demonstrate AR's benefits in the classroom, the use of AR technology alone may not solve the natural interaction problem in education. This is because, in order to trigger a computer response by the optical capturing of markers in an AR application, learners need to map the interactive operation to the intermediary medium. For example, in the convex imaging experiment proposed in (Cai et al. 2013), learners need to (1) operate 2D-code cards to change the object distance and the distance between the object and the lens and (2) imagine that the 2D-code cards are the experimental facilities. The learning effects could have been compromised due to the increased cognition load caused by the information migration. The experiment would have been more interesting if not only the virtual objects were integrated into a real scenario with AR, but also the learner's interactive operation behaviors were the same as the real experimental condition. The latter is the human–computer interaction technology which is representative of a motion sensing interaction.

In recent years, free motion sensing interactive technologies that can replace a keyboard and mouse have impacted educational practices in significant ways (Johnson et al. 2013; Johnson et al. 2012; Johnson 2014, 2015; Johnson et al. 2010; Johnson et al. 2011). Stemming from games, this motion sensing technology enables users to operate and control games through gestures and body motions. Utilizing this technology usually requires a proper hardware and software package. Some cases have shown the potential of Augmented Reality-based natural interaction technology in educational field. In November 2010, Microsoft Corporation released a motion sensing device called Kinect, which contributed to a wave of motion sensing device applications. Researchers at the Vienna University of Technology had demonstrated the application of AR technology in teaching mechanics (Kaufmann and Meyer 2008). It used a physics engine to develop computer games, simulating experiments in the field of mechanics in real time. The students actively created their own experiments and studied them in a 3D virtual world. Before, during and after the experiment, the system provided a variety of tools to help students analyze the force, mass, motion paths and other physical quantities of the target object. However, since the system required expensive helmets, stereoscopic glasses and other equipments, the learning experience might have been undermined. Researchers from Arizona State University developed a multimedia art learning environment in mixed reality called SMALLab (Johnson-Glenberg et al. 2011), which allowed students to learn through the body's 3D motion and hand gestures in a PC-simulated collaborative multimedia space. They designed a series of collaborative learning solutions based on the environment mentioned above under the guidance of a community team composed of professional K-12 teachers, students, media researchers and artists. Even though the simulative teaching environment was created by combining motion sensing and AR techniques, the environment requires a separate space and sophisticated equipment. Chang et al. (2013b) developed Kinempt (Kinect-based vocational task prompting system), which allowed individuals with cognitive impairments to accomplish task objectives independently through prompted steps. The evaluation found that the system, combined with specific operating strategies, can effectively enable these particular individuals to obtain job skills.

AR-based natural interaction technology has also been applied in teaching magnetism. In the AR simulation developed by Buchau et al. (2009), a previously calculated magnetic field is applied, while it is static with invisible real-time effects and two-magnet models are absent. Mannus et al. (2011) taught basic magnetic concepts with two handheld devices and AR techniques, which demonstrated that AR techniques improved the students' understanding of magnetic fields. Matsutomo et al. (2012) simulated the magnetic induction line and AR images presented in real time and designed a dependent magnetic model and magnet-current model based on the teaching application. One year later, Matsutomo et al. (2013) further refined the model, moving and plotting the distribution of the magnetic induction line on a monitor by using a specially prepared bar-like fake magnet. Ibáñez et al. (2014) have found that the AR application can effectively improve students' understanding of electromagnetic concepts and phenomena. They also determined that, compared to Web-based application, AR-based application enables students to obtain higher-level experiences.

As these applications show, an AR-based simulation has more advantages than the rigid mouse-controlled mode. This conforms to the AR operational advantages generalized by (Carmichael et al. 2012) from cognitive theory, including the use of reality, virtual flexibility, invisible interface and spatial awareness. From the perspective of virtual flexibility, this will create a wider space to liberate users from the use of mouse and keyboard. Carmichael et al. (2012) believed that multiple advantages can be utilized to enhance the AR system efficiency (the better a learning system is designed, the better the AR works as an interface). Vogt and Shingles (2013) experimentally demonstrated that the AR technology can be independently applied and utilized by users without specialized knowledge. In the virtual simulation learning context, the presentation effect of abstract objects is subject to the level of students' prior knowledge and the difficulty of the learning content. With sufficient prior knowledge, whether we use abstract objects in teaching causes no impact on learning; this suggests that the influence of a technological innovation must be closely correlated with the student's prior knowledge. This also leads to the question of what influence an AR-based authentic learning environment has on students with different levels of prior knowledge. Does it affect students' in-depth cognition? How can we evaluate the effect of AR technology on learning? In this chapter, we present several AR-based learning cases to explore the influence of an AR authentic environment on learners' attitudes and learning outcomes.

## 3 Case Studies in AR-Based Learning Environment

We introduce five case studies in AR-based learning environment in different disciplines, including probability learning in mathematics, convex imaging experiment and magnetic field study in physics, inquiry-based microparticles interactive experiment in chemistry and EFL children's vocabulary study in language learning.

## *3.1 Case Study in Mathematics: Probability Learning*

The main goal of this study was to investigate the influence of Augmented Reality on the secondary school students' learning experience as well as the learning achievements (Li et al. 2016).

### 3.1.1 Participants

Fifty-nine seventh grade students in a middle school of an urban–rural fringe area participated in this study. At the beginning, the experimental group had 31 participants and the control group had 28 participants. Six participants in the experimental group and 3 participants in the control group were removed from the final analysis of the study due to the incompletion of responses.

### 3.1.2 Research Design

We implemented a mobile game, magic coins, using AR technology on Android OS. Before the start of the first round of the game, students can set two parameters: interval time and recognition time. Interval time refers to the shortest time between two rounds of recognition, and recognition time refers to the shortest time the coin stays in front of the camera. When playing the game, the camera captures the head side or tail side of the coin and the screen will show 3D model in the reality scene in order to prompt students to a successful identification as shown in Fig. 1. Once the recognition is successful, the system will record and update the numbers of head side or tail side as shown in Fig. 2. When students exit the game, the historical data will be recorded in the local database for students to access.

### 3.1.3 Research Findings

Pretests and posttests were given to students, respectively, to measure the learning achievements of the students. To be specific, the pretest consisted of ten blank-filling questions to assess the participants' prior knowledge of the subject matter: Four addressed empirical probability, four addressed theoretical probability and two addressed the relations between the two probabilities. The posttest consisted of five blank-filling questions to assess the students' learning achievements: One of them addressed empirical probability, two of them addressed theoretical probability and the rest addressed the relationships. In addition, five open-ended questions were also created to determine the AR learning experience of students.

We find that in the pretest the mean score of students in the experimental group is lower than the ones in the control group. On the other hand, the mean score in the posttest of students in the experimental group is higher than that in the control

**Fig. 1** The camera caught the tail side of the coin

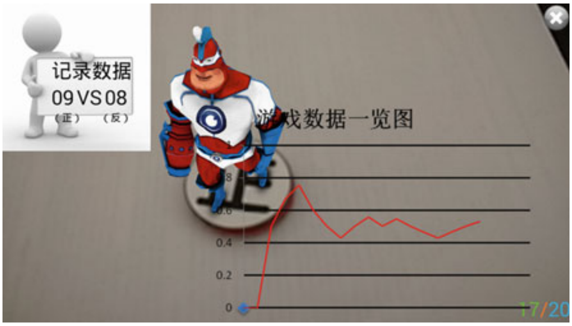


**Fig. 2** The system recorded the numbers of the coin's head and tail side and updated the line graph of the empirical probability of the head side

group. The improvement in apprehending the relations between empirical probability and theoretical probability in the experimental group was to some extent better than that in the control group. Such insignificance indicated in the data we collected may be explained by the relatively small class size and other research limitations.

Nevertheless, despite the fact that the quantitative analysis of students' learning achievements was not statistically salient, the qualitative analysis of the answers to the open-ended questions in the posttest illustrated strong improvement of student engagement in the mathematical learning process under the instruction that featured Augmented Reality technology.

## *3.2 Case Study in Physics: Convex Imaging Experiment*

The main purpose of this case study was to explore eighth graders' learning achievements and learning attitudes toward the convex lens experiment with AR instructional applications (Cai et al. 2013).

### 3.2.1 Participants

Two classes of eight grade students from Nankai Foreign Language Middle School in Tianjin, China, participated in this study. The experimental group consists of 24 students (female, 16; male, 8), using AR tools as a supplemental instructional activity; and the control group consists of 26 students (female, 14; male, 12), proceeding with their traditional instruction. The two classes' selection process was based on students' previous academic achievements.

### 3.2.2 Research Design

This study incorporated a quasi-experimental design consisting of a questionnaire survey in order to collect data on learning outcomes of convex lens image forming experiment and students' learning attitudes toward using AR tools. This study followed a pre-post test with an additional posttest quantitative measure in the experimental group. The research objectives of this study are as follows: (1) to compare physics learning achievement between the experimental and control groups and (2) to explore students' feelings about the AR tools learning after they experienced it.

Convex imaging Augmented Reality teaching aids can directly simulate convex imaging experiment, by using three different markers to substitute candle, convex and fluorescent screen. 3D model of convex, and a straight line parallel to the axis which is used to mark focal length and twice focal length, will be displayed on the screen when the camera captured the convex marker. By putting the candle marker and the screen marker on each side of the convex marker, respectively, the screen will automatically present relevant objective image based on the position of the distance from candle to convex, as shown in Fig. 3. If the distance between candle and convex is adjusted, the image on screen would change correspondently and simultaneously according to the convex imaging rule.

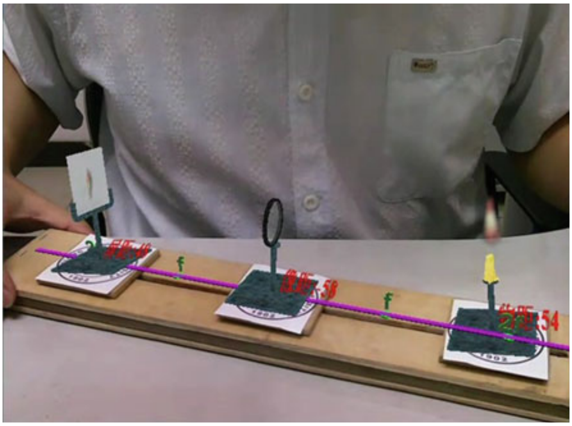

**Fig. 3** AR simulation convex imaging experiment

Assuming object distance as $u$, image distance as $v$ and focal length as $f$, when $u < f$, virtual image will be visible, according to the formula of convex imaging $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$.

After the teacher instructed students how to use AR tools, students from the experimental group have to practice and learn these concepts of convex imaging with AR tools. Meanwhile, students from the control group studied the same learning content through traditional instructional methods. Figure 4 illustrates the process of students' accomplishing convex imaging experiments.

### 3.2.3 Research Findings

The study revealed that mean scores indicated by the experimental group increased more than those indicated by the control group, yet there appeared to be no significant difference between the two groups in posttests. In addition, most students have positive attitudes toward using AR for their learning in physics courses. They

**Fig. 4** Students accomplishing convex imaging experiments

contended that AR tool instructional applications can attract their attention and promote their learning motivation in physics courses, according to the results of learning attitudes questionnaire. Although there is insufficient evidence to determine whether students' conceptual understandings can be promoted, AR tools applications provided students with different opportunities for science learning. Furthermore, AR tool experiments not only scaffold students' understandings of concrete and observable physics concepts, but also assisted the development of experimental skills through practical experiences.

## *3.3 Case Study in Physics: Magnetic Field Visualization*

In this study, we used AR and natural interaction technology in a class that teaches magnetic fields to explore the influence of an AR natural interactive environment on learners' attitudes and learning outcomes (Cai et al. 2016).

### 3.3.1 Participants

The sample consisted of 42 students in grade 8 at a junior high school in Beijing, China. Prior to the experiment, students in the sample were randomly divided into two groups: Groups A (control group) and B (experimental group). Each group was divided into five subgroups with roughly four students in each subgroup.

### 3.3.2 Research Design

We built a magnet and magnetic induction line model based on Biot–Savart law using 3D modeling tool *3DS Max* and graphics engine *Java 3D*. Then, we situated the model on Kinect environment and adjusted coordinate system as well as the interactive mode between users and model. With the help of the built-in RGB camera of Kinect, the system can render real-time virtual models and the real scene to present a mixed interactive environment. The depth camera also helped to return the distance between users and the Kinect device, so we were able to control the rotation of the virtual model by changing the relative distance.

The system included four parts: a magnetic induction line model 1 with a magnet and small magnetic pins (Fig. 5a), a magnetic induction line model 2 with a magnet and magnetic pins (Fig. 5b), an S-N model with two magnets and a small magnetic pin (Fig. 5c) and an N-N model with two magnets and small magnetic pins (Fig. 5d), as shown in Fig. 5.

**Fig. 5** Magnetic induction line model

### 3.3.3 Research Findings

#### Overall Analysis of Test Results

According to test scores, while the prior scores of both groups were not significantly different, the average scores of Group B of immediately after and one week after the experiment were both higher than Group A's. One the one hand, that the average score of Group B one week after the experiment was higher than Group A's suggested that the inquiry experiment in the AR-based environment with the motion sensing devices had a positive influence on students' learning and was able to maintain that the positive influence for a longer time. On the other hand, the difference between the two groups was not statistically significant.

#### Attitude Questionnaire Analysis

On the whole, students' responses to the attitude questionnaire were positive and showed that they were excited and optimistic about the new technology and software. The questions that had the highest scores were students' interest in physics, inquiry learning and AR-based motion sensing technology; lower scores occurred on the interface design, such as the software color and layout. This suggested that the software resulted in the anticipated effect on the experimental group (Group B). Issues raised by the feedback were consistent with our expectations and will be further resolved and improved in future researches.

## Students' Perspective on AR-Based Natural Interaction Learning

After the lesson of the experimental group, we randomly selected four students (numbered as S1, S2, S3 and S4) for interviews. We expected students to share their feelings about the teaching method as well as comment on the AR-based motion sensing program in the experimental operation. From the interviews with students, we can draw the following conclusions:

(1) Most of students felt that the lesson was very novel and interesting.

Compared to the control group, we added the AR-based motion sensing program in the experimental group and the students worked on their own. The students had not observed the AR-based motion sensing program before. Some students had heard of the technology, but none of them experienced it in classroom. Therefore, for the students, the method was very innovative and interesting. They thought it was *"very novel because Augmented Reality is a new interactive way that hasn't been done before"; "I felt the lesson was very uniquely designed"; "I have not used the motion sensing technological software before, but have played games, and I felt it was novel in learning"; "The lesson and what was learnt together with everybody were very new. If the method is used in class, it will be of interest to students."* Additionally, compared to the traditional inquiry teaching method, the experimental course in a problem-based explorative mode was welcomed and affirmed by the students. In a word, students were impressed by the AR and motion sensing technology display and experiments because the AR and motion sensing technology applications attracted their attention.

(2) The course result of the experimental group is satisfactory.

We found that the interviewed students expressed that they understood the knowledge system of magnetic induction lines and even affirmed that they have grasped all of the checkpoints. They believed*: "the lab facilities used in the experiments can be reduced and found again in the virtual world, which helped us easily approach to the knowledge, understand it better, and master it eventually"; "I felt it was playable, students who love it would get intrigued in it, and then grasp the knowledge better. This method is brand-new. If the method is applied in class, students' enthusiasm will be stimulated. Moreover, the instructor teaches very well, and the PPT was also well-designed"; "I have grasped 90% of the above."* These expressions showed that the students were acquiring knowledge of magnetic induction lines. Therefore, we are convinced that the teaching method of using AR-based motion sensing software can bring about positive teaching outcomes.

## 3.4 *Case Study in Chemistry: Inquiry-Based Microparticles Interactive Experiments*

This study mainly focused on the supplemental learning effect of AR-based learning tools in a chemistry course (Cai et al. 2014).

### 3.4.1 Participants

This study involved 29 students in grade 8, including 16 boys and 13 girls. The experiment of the software's impact was conducted in a junior high school in Shenzhen, China.

### 3.4.2 Research Design

The class taught content related to "The composition of substances" only during the week covered in this experiment. Before this study, we interviewed the chemistry teacher, she pointed out that her students were not very motivated and did not completely comprehend the learning materials, which were perceived as dull and abstract. Therefore, she expressed a wish to review the content using an AR tool in order to promote learning attitudes and learning effects. For these reasons, the experiment did not include a control group. Pretest scores would represent students' learning outcomes when textbooks are used, and posttest scores would represent students' learning outcomes after using an AR inquiry-based learning tool. None of the tools used in the activity, including the software, markers and activity form, presented the exact knowledge points included on the test, which means that students' test answers must be the outcomes they achieved by themselves through their observation and exploration during the inquiry-based learning process. Additionally, in this case, we believe that the vertical difference between pretest and posttest scores would represent the AR tool's learning effect. The questionnaire primarily investigated students' learning attitudes toward this AR learning tool.

#### Experiment Design

The subjects of the empirical study are the 29 students (16 boys and 13 girls) of class 9, grade 2. Before the experiment, researchers installed the AR software on each computer of the classroom. The experiment design contains 4 sections as shown in Table 1.

**Table 1** Experiment design

| Experiment content and operation methods | Source of measure instrument |
|---|---|
| Pretest: a paper-and-pencil quiz test every student, required to complete independently | The quiz was devised by Ms. Shengyan Wan of Meishan Junior High School, Shenzhen |
| Divide the class into groups of 3 randomly. Each group is required to use the AR tool to learn as indicated on the exploration form and complete the form in cooperation without teacher's guidance. (the tool contains AR-based software, markers and the activity form) | The exploration form is devised by the researcher, which corresponded with the software and the learning objectives |
| Posttest: repeat the same quiz test in pretest | The paper quiz test was the same with the one in pretest |
| Paper-and-pencil questionnaire survey with every student, required to complete independently | The scale consists of 4 constructs, which, respectively, based on the following 3 papers with minor revisions: learning attitude (Hwang and Chang, 2011), satisfaction toward the software (Chu, Hwang and Tsai, 2010a) and cognitive validity and accessibility (Chu, Hwang, Tsai and Tseng, 2010b)) |

### Application Design

The software was programmed in Java and the extra packages used included NyArToolkit, Java 3D and JMF (Java Media Framework). In addition to accurate modeling, the essence of human–computer interaction with this software is to detect and record the position of each marker in the camera's view, as the application will trigger different animations when the marker is at different positions. That is, the interaction between users and computer is position-based. In other words, we used position of markers to present different phases of a structure and various combinations of atoms. The markers' behavior can be consistent with real particle behaviors in some cases, while being inconsistent in other cases. For example, when two markers get closer, a new molecule can be formulated, which is what really happens in microworld. In another example, when lifting a marker, the molecule changes from molecular structure into substantial form, or specifically from $H_2O$ molecular structure into a water drop. The behavior "lifting a/an molecule/atom" does not really happen in microworld, whereas with these special behaviors and operations, we expect students to acknowledge the transformation between atoms, molecules and substances. The following figure shows operation screens from two applications, the water and the diamond cases.

As shown in Fig. 6a, three atoms, including 2 hydrogen atoms and 1 oxygen atom, are interposed in the scene. When we move the two hydrogen atoms close to the oxygen atom, a water molecule is formed, as shown in Fig. 6b. Users are allowed to lift the water molecule closer to the camera to view its structures, and if we keep lifting, it turns into a water drop, as shown in Fig. 6c and d.

(a) Models of three atoms (b) Three atoms form a water molecule (c) The structure of a water molecule (d) Water molecules from a real water drop

**Fig. 6** Water molecule interaction

In the second application, the inquiry-based activity requires students to construct the diamond crystal using carbon atoms. First, we construct a basic tetrahedron unit of diamond crystal using carbon atom and chemical bond, as shown in Fig. 7a. Further we will use this unit to construct a more complete structure of diamond crystal, as shown in Fig. 7b. Students can get hints from another marker to deduct the structure they have built is the structure of diamond, which combines chemistry with daily social life.

After students finished the inquiry-based activity, researchers expected them to (1) know that there are three particles that can compose substances, explain the formulation of water, graphite, diamonds and NaCl, understand the structure of atoms of different elements and connect the features of substances with microstructures; (2) be able to generalize abstract concepts and master basic chemistry research methods; (3) form the habit of respecting objective facts and a serious attitude toward science and inspire interests in learning chemistry.

### 3.4.3 Research Finding

Most students looked excited, curious and motivated during the inquiry-based learning activity. During the process of the whole experiment, researchers observed carefully and made records of students' performance. The first 2 groups to

(a) Basic unit of diamond crystal (b) Part of diamond crystal

**Fig. 7** Diamond crystal interaction

accomplish the whole activity were all boys. At first, 2 girls did not participate in the learning activity; meanwhile, they were doing homework; with the teacher's encouragement, they joined the experiment later. We found that most students did not like to consult the papery activity form; on the other hand, they like to interact with the software on their own. According to the responses of the activity form, we found there were conspicuous mistakes which can be avoided with careful observation and proper teacher guidance.

After the experiment, we picked 5 students tested randomly for face-to-face interviews. In the interview, we asked them to talk about their feelings about the learning tool. First of all, they admitted the AR tool could help them remember the structure of atoms. In traditional class, it is difficult to remember all these with merely teacher's plain instruction. On the contrary, the software was more attractive which left a deeper impression in their mind. Secondly, compared with previous flash courseware and other 3D modeling software, AR tool helped them develop their operation capabilities. The natural and direct interaction was better than keyboard and mouse interaction for them to remember especially the procedural knowledge. At the same time, students also proposed some suggestions toward this tool. Firstly, the model could be instable and twinkling at times. Moreover, they hoped that the simulation of substances can be more analogous to reality. Thirdly, they suggested that some cartoon or animation elements to make the software more fascinating. Last but not least, when the researcher asked the 5 student interviewees whether they would like to use AR tool in their future studies, they said "yes" with one accord.

## *3.5 Case Study in Language Learning: EFL Children's Vocabulary Study*

This study investigates the learning achievement of students as well as teacher's attitude after participating in the mobile-based AR learning activity (He et al. 2014).

### 3.5.1 Participants

The participants were from two classes of a preschool in Beijing, China, whose ages ranged from four to six. There were 20 children in each class. One was assigned to be the experimental group named A, while the other was the control group named B. None of them had experience in mobile devices and the new words were never taught before.

### 3.5.2 Research Design

The mobile learning application used to arouse interest in learning English has been developed with AR (Augmented Reality) technology. This system was implemented with Java 1.7 Android SDK and Wikitude SDK. The functions of the application include fetching and recognizing words, showing the corresponding picture and pronunciation.

Figure 8 shows the users' interface of the mobile AR application. The top one is the welcome page, including three buttons—"Fetching Words," "About the Developers" and "Exit." By clicking "Fetching Words" button, learners can enter the "the word-fetching page" of the application. Aiming at the words on card with the mobile camera, it will show the clickable corresponding picture. The application will pronounce the word after the click. Learners need to fetch the word, connect it with the appearing picture, click it, listen to the pronunciation and repeat them. Figure 9 shows the experimental students are studying words using the mobile-based AR application.

### 3.5.3 Research Findings

The "learning achievement test" were conducted before and after the experiment. As there are unavoidable difficulties in testing the attitude of the kindergarten children, we interviewed the English teacher of the class at the end of the experiment.

#### Analysis of Learning Achievement

To explore whether mobile-based AR learning activity was helpful in this experiment, an independent test was used to collect data from the pre- and posttest of the two groups. We found that the students in Group A have made remarkable progress,


**Fig. 8** Users' interface

**Fig. 9** The experimental students are studying words using the mobile-based AR application

as their mean score changes from 23.125 to 73.125. No significant difference ($p = 0.930$) was found in the pretest of the experimental and control group, but an extremely significant difference ($p = 0 < 0.001$) appeared in the posttest between the two groups. Hence, we can conclude that mobile-based AR learning software is helpful for students who are non-native speakers in learning English vocabulary.

Analysis of Teacher's Attitude

Since the kids in kindergarten were too young to express their attitude, and in order to have a deeper understanding of this experiment, we interviewed the English teacher of these two classes. The teacher's opinions are summarized as below. "This type of learning combines tactile sense, auditory sense and visual sense together. It is easier to mobilize the kids' enthusiasm. That using mobile phone to scan words, present matched pictures and the pronunciation aligns with the cognitive rules of children. However, mobile phones may distract students' attention. This type of teaching may be more suitable for one-to-one situation. Also, the number of vocabulary may have been too large for kids at these young ages. It would be much better if a comprehensive learning environment was created in the beginning."

## 4 Conclusion

From those cases above, we could see that only a computer or mobile device with a camera can achieve real-time interactions between students and 3D virtual learning materials based on AR, which satisfies the instructional requirements of the interaction and the exemplification of abstract knowledge. In general, students possess a positive learning attitude and provide positive evaluations of the AR tool, which is consistent with the results of Nunez et al. (2008). Furthermore, there exists a significant positive correlation between students' learning attitudes and their evaluation of the AR tools.

Finally, we predict five trends of AR learning environment. (1) It will enable users to participate in the composing process. AR-based learning environment returns the rights of composing learning materials to users. Learning contents and activities are both designed and accomplished by students, which indeed embodies the concept of student-centered. (2) More exploration space will be provided. When teaching activities are migrated into an AR-based environment, traditional interactive methods may not be suitable. How to design teaching activities, how to realize better communication between learners, etc., are all questions to be discussed and solved by developers and educators of the blended AR environment. (3) It will combine with learning management system. The integration of the AR-based learning environment with existing 2D information systems and 3D virtual environments requires further exploration on how this integrated environment can elevate learning outcome and keep with existing and new teaching methods. (4) It will merger with intellectual technologies. Ideal AR-based learning environments can imitate real teachers' experience, methods and behaviors, and automatically fulfill the task of analyzing and explaining students' questions. (5) It will connect with mobile technologies. At the present, the AR application on mobile device remains on a 2D level such as geographical positioning. How to ensure the 3D learning experience of AR on computers and at the same time enable learners to enjoy mobile learning anywhere at any time needs unyielding efforts from both technicians and educators.

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# Part III
# Optimizing Learning Environment for Authentic Learning

# Authentic Learning of Primary School Science in a Seamless Learning Environment: A Meta-Evaluation of the Learning Design

**Lung-Hsiang Wong and Chee-Kit Looi**

**Abstract** A group of researchers had been working on a longitudinal mobile learning (m-learning) project in a primary school in Singapore. A curriculum design framework was proposed in the beginning of the project to guide the two-year design-enactment-reflection-refinement cycles of the mobilized curriculum. In this chapter, we narrate our implementation research approach by presenting a post hoc analysis of how the curriculum was progressively transformed for seamless learning (a learning notion that advocates perpetual learning across contexts) and how the design taps on the affordances for m-learning. The evaluation illuminates how various types of learning activities are systematically introduced in the two years of science curriculum to nurture inquiry learning across both formal and informal contexts, thus supporting notions of authentic learning. This chapter contributes to the literature on how to address challenges in translating learning theories and integrating mobile technology affordances into curriculum development and sustainable classroom practices.

**Keywords** Authentic learning · Mobile learning · Seamless learning · Mobilized curriculum · Science learning · Instructional design

## 1 Introduction

"Time for science lessons, take out your phones!" This was the title of the news article published on a national newspaper (The Straits Times, November 22, 2010) on our school-based research study in 1:1 computing for 24/7 (24 h a day, 7 days a week) access to mediate the students' classroom and out-of-classroom learning. The

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title aptly captures the essence of the changes our study had brought to the Primary 3–4 (3rd–4th Grade) experimental classes after two years of design and enactment of a mobilized curriculum (Norris and Soloway 2008). By "mobilized curriculum," we refer to a curriculum that starts with the existing specification of content structure and learning goals, but then is transformed to incorporate the mediation of mobile technologies' affordances. The "mobilized curriculum" is a transformation from a more content- and teacher-centered classroom practice to the provision of a student-centered, cross-contextual learning experience to foster personalized, self-directed, and authentic learning (Looi et al. 2009; Zhang et al. 2010). Authentic learning comes about as learning that is seamlessly integrated or implanted into meaningful, "real-life" situations (Jonassen et al. 2008).

This work concurs with Van T' Hooft and Swan's (2004) vision that ubiquitous technology has become integrated into the curriculum so that the students no longer have to fight over whose turn it is to use one of the few desktops in the classrooms. In addition, 1:1 computing for 24/7 access can extend student learning beyond the four walls of the classrooms, with the mobile devices functioning as a personal "learning hub" (Wong 2012; Wong and Looi, 2010) that facilitates personalized learning journeys for each student. Therefore, it is not surprising that such "1:1, 24/7 programs" have been experimented or enacted at K-16 levels in many parts of the world in the past entire decade (e.g., Anastopoulou et al. 2012; Cochrane and Bateman 2010; Kerawalla et al. 2007; Zheng et al. 2014).

Despite extensive academic publications in this topic, Bebell (2005), Dunleavy et al. (2007), and Lei and Zhao (2008) noted that most studies provided only general, descriptive reporting or evaluations on "what" (tools or affordances) was used, "how much" was used, and the changes to "what" and "how much," and they relied heavily on interviews and observations as their data sources (e.g., Cochrane and Bateman 2010; Crompton and Keane 2012; Hartnell-Young and Heym 2008). Other studies looked into proposing specific theory-based learning models to inform curriculum mobilization (e.g., Cobcroft 2006; Mezler et al. 2007; Moura and Carvalho 2008), performing needs analysis through teacher surveys (e.g., Shuib et al. 2010), discussing what and how emergent technologies can be incorporated into mobilized curriculum (e.g., Bunce 2010; Myers and Talley 2007), developing their own technologies for specific purposes (e.g., Liu and Chu 2010; Wang et al. 2009), developing survey instruments for assessing such programs (e.g., Lauricella and Kay 2010), and studying student and/or teacher perceptions on such programs (e.g., Christensen and Williams 2015; Zheng et al. 2014). Nevertheless, the actual process of curriculum (re-)design and the evaluation of such mobilized curricula remain a research gap.

We believe that a key reason is that most scholars in the fields of science education or learning sciences do not position themselves as curriculum designers in their embedded or interventional studies. They usually came into the K-16 institutions either as researchers designing a specific, often episodic, intervention, or as external assessors of existing programs, or as the developers of higher-level design frameworks or technological infrastructures, while teachers or curriculum designers took up the responsibilities of developing the whole curricula, with or without researchers' guidance. A notable exception is the project-based inquiry science for middle school which developed a comprehensive 3-year project-based inquiry science curriculum for middle school (National Research Council 2010).

Albeit fairly receptive to technology-mediated instruction, teachers designing new curricula might not necessarily possess deep understanding of the critical success factors behind the technology-enabled intervention. Furthermore, much of the professional development of the 1:1 initiatives they had been through tended to focus on the training of technological affordances but not so much on their epistemological beliefs and the capability of adapting and sustaining mobilized curricula (e.g., Silvernail and Lane 2004).

Our critical analysis of the classroom mobilized activities as reported by the reviewed papers reveals that most of the reported efforts were not genuinely holistic curriculum re-designs. Instead, the mobilized lessons were in general the "plugging in" of mobile technology usage, such as the change of medium (from paper-based to digital learning tasks, or from printed textbooks to digital learning materials), behaviorist quizzes or assessments, additional requirements of Internet searches, etc. In most cases, there was no fundamental change in the classroom practice other than digitalizing certain aspects of the teaching and learning processes, thus lacking authenticity in the learning process, which had perhaps reflected the relatively weak theoretical foundation behind their learning designs.

Conversely, some interventional studies (e.g., Evans and Johri 2008; Martin and Ertzberger 2013; Santos et al. 2014) may have developed m-learning models for 1:1 initiatives with good pedagogical and theoretical grounds such as project/inquiry-based learning, constructivist learning, situated learning, and collaborative learning. However, exactly how the introduction of these models had impacted the re-design and enactment of the existing curricula, and whether and how subsequent classroom practices were transformed were often not clearly reported. These could be attributed to the gap between educational research and practice, as posited by Sabelli and Dede (2001).

The questions we are interested in are: In 1:1 initiatives, to what level are the changes in classroom practices acceptable by both the formal school establishment (e.g., not to jeopardize the students' pursuance of the learning goals and academic standards imposed by the authorities) and the researchers with the agenda of advocating pedagogical reform? As abrupt changes are usually not feasible, how should gradual reforms take place? As researchers, how should we manage the school leaders' and teachers' expectations in striking a balance among different agendas and needs?

In this regard, and under the auspices of the three-year SEAMLESS project (Zhang et al. 2010; Looi et al. 2011) on 1:1 computing at the primary school level, we transformed the existing science curriculum for Primary 3–4 (P3 and P4) into a mobilized curriculum. The project is known as SEAMLESS as it is framed in the broader context of constructing "seamless learning" environments to bridge different learning contexts, mediated by mobile devices in 1:1, 24/7 basis (Chan et al. 2006; Milrad et al. 2013; Wong et al. 2015). Distilled from our team's literature review and prior research findings, we developed a ten-dimensional framework known as “10D-MSL” to characterize mobile-assisted seamless learning (Wong, 2012; Wong and Looi 2011). The ten dimensions are:

- Encompassing formal and informal learning
- Encompassing individual and social learning
- Learning across time
- Learning across locations
- Ubiquitous access to learning resources (online information, teacher-supplied materials, student artifacts, student online interactions, etc.)
- Encompassing physical and digital worlds
- Combined usage of multiple device types
- Seamless and rapid switching between multiple learning tasks
- Knowledge synthesis (prior and new knowledge, multiple levels of thinking skills, and/or cross-disciplinary learning)
- Encompassing multiple pedagogical or learning models (facilitated by the teachers)

Thus, seamless learning could simply be characterized as “seamless flow of learning across contexts.” The basic rationale is that it is not feasible to equip students with all the skills and knowledge they need for lifelong learning solely through formal learning (or any one specific learning context). Henceforth, student learning should move beyond the acquisition of content knowledge to develop the capacity to learn seamlessly (Chen et al. 2010).

The mobilized curriculum is expected to address learning objectives in the existing curriculum that follows the existing curriculum schedule and yet affords the possibilities for deeper learning and engagement in science, and personalized learning across contexts (Looi et al. 2011; Song et al. 2012). The design of the curriculum resonates with several of the design elements of the authentic learning experience, namely real-world relevance; sustained investigation; multiple sources and perspectives; collaboration; reflection (meta-cognition); interdisciplinary perspective; integrated assessment; polished products; and multiple interpretations and outcomes (Lombardi 2007).

In this chapter, we will evaluate four representative mobilized units arising from the curriculum that we co-designed and enacted in order to illuminate the detailed design process of activities for classroom and out-of-classroom learning. For this purpose, we adapted and applied a framework proposed by Frohberg et al. (2009).

We will also describe how the school management’s involvement in the end of the first-year lesson enactment had impacted our subsequent curriculum design, which exemplified the often inevitable tension between research and practice (Wong et al. 2011). We will discuss implications and lessons learned for guiding subsequent work. Our curriculum design was done simultaneously, iteratively, and collaboratively with the teachers. As our mobilized curriculum was not a direct output from a pure academic-driven design exercise, we step aside from the role of practice-minded co-designers to evaluate individual lesson plans (both in terms of their design and some notable outcomes in the enactment) through an academic lens. In doing so, we wish to contribute to the literature on how to address challenges in translating learning theories and in integrating mobile technology affordances into curriculum development and sustainable classroom practices.

## 2 Context of Curriculum Design Process

We collaborated with a Singapore primary school to explore a sustainable model for integrating 1:1 mobile technology into student-centered, inquiry-based learning. In our three-year collaboration, we first studied the existing national science curriculum (Ministry of Education 2008) and learned about its overarching vision, "Knowledge through Inquiry," and its adoption of the BSCS (Biological Sciences Curriculum Study) 5E model (Engage, Explore, Explain, Elaborate, Evaluate) (Bybee 2002) as the guiding structure in inquiry lesson design. Besides the state-authorized science textbooks, there are complementary student activity books (workbooks) that contain assignment questions for students to complete at various points of each lesson. In the curriculum design and classroom practices prior to our intervention, it was mandatory for the students to complete most of the prescribed activities. The activity book assignments are rather structured and typically comprise exercises that require students to recall knowledge rather than carry out inquiry activities. Nonetheless, the school management viewed it as a critical tool to ensure the students learn how to answer examination-style questions.

In the first year, we followed a Primary 3 (10-year-old students) mixed-achievement class of 30 students to first observe and understand the existing teaching and learning practices. A curriculum task force involving teachers and researchers met weekly to develop a methodology for designing the mobilized science curriculum. Such an approach is known as collaborative inquiry (Darling-Hammond 1996), based on the notion that collaboration between research and practice is likely to advance both knowledge and action (Batliwala 2003). Hence, collaborative inquiry could serve as a means of teacher empowerment and professional development, aided by researchers' consultations and support, in leading them to take charge of their own growth and to resolve their own problems (Keedy et al. 1999; Walter and Gerson 2007; Wong et al. 2011).

The outcomes were the specifications of a series of mobilized lessons, known as MLE (mobile learning environment) units in our project. Each unit was based on one overarching goal that pertains to one topic or encompasses several topics in the original curriculum (though not necessarily following the original instructional sequence) and spanning through a period of one to five weeks in enactment. Each unit consists of a series of learning activities, some of which may be carried out during the formal science lessons in the classroom, out-of-class (but at designated time, such as field trips or during recess time), and out-of-school (at students' own time when they are back at home or in their neighborhoods). The activities may or may not involve the use of their smartphones. The curriculum co-design was an ongoing process. That is, the task force did not design the whole science curriculum in one go before the intervention commenced. During and after each design-enactment cycle for a MLE unit, the teachers and researchers were able to reflect upon the lessons and apply such understanding to inform the design of the next MLE unit.

The research work also involved the pilot testing of the co-design curriculum units in classroom settings. In the second year, we continued working with the curriculum task force and the experimental class which has moved up to Primary 4. We also spread the intervention to another high-ability Primary 4 class taught by another young teacher. Both classes deployed the same mobilized curriculum.

For the intervention, each of the students in the experimental class was assigned a HTC™ TyTN II smartphone which runs the Microsoft™ Windows Mobile 6 for 24/7 access. The school purchased the smartphone with an unlimited 3G data plan for the students. The smartphone was equipped with a digital camera and with the bundled software of calculator, calendar, MS™ Mobile Word, Excel, and PowerPoint. Besides these standard affordances and software, students and teachers needed explicit software support for the inquiry learning approach. For this, the GoKnow™ MLE (mobile learning environment) was selected. It served as a malleable environment to support the specific inquiry-based teaching and learning strategies in our curriculum design. The software suite consists of PiCoMap (for concept mapping), Sketchy (for production of simple animations, either with a set of freehand sketches or photographs), KWL (a word processing template software for filling up "What do I already Know? What do I Want to know? What have I Learned?"—to stimulate students' curiosity), and GoManage server (for teachers to perform learning management and automated backup of student artifacts). In the second year of the intervention, two additional software tools were developed at different stages: Mobile Forum (a mobile-optimized online forum) and ColInq ("collaborative inquiry," affording students to upload and share geo-tagged text and multimedia artifacts either during teacher-facilitated field trips or on their own during their informal learning).

We designed our mobilized curriculum to be student-centered, inquiry-based, and collaborative in nature. With the use of the smartphone as a learning hub to integrate formal and informal learning activities, each student created and maintained a broad range of artifacts associated with each curriculum unit. In the curriculum design, we applied the following six guidelines with consideration of foregrounding an inquiry science approach and the affordances of the mobile technologies:

- Design student-centered inquiry-based learning activities (learning);
- Exploit the affordances of mobile technologies to be woven into the fabric of the learning activities (technology);
- Assess student learning formatively by teacher and peer evaluations of student artifacts during and after class (assessment);
- Facilitate collaborative interactions among students through and over the hand devices (collaboration);

- Make use of community support and resources, such as field trips to the local zoo and the science center (community resources);
- Support teacher development to be good developers and facilitators, which was achieved through the collaborative inquiry process (teacher's professional development).

The designed MLE units were packaged into GoKnow's MLE MyProjects, which could be accessed by the students on their smartphones as shown in Fig. 1. A lesson overview depicted in Fig. 2 shows students the objectives of the lesson and what is expected from them in learning about the body system.

We designed a total of twelve MLE units in the two years of intervention. In addition to offering a logical flow for learning the subject matter knowledge, we had progressively incorporated various types of inquiry/seamless learning activities, from simpler to more demanding ones. This was to facilitate the students' gradual changes in their habits of mind moving toward learning seamlessly and learning by inquiry. We provide a categorization of the 10 major types of smartphone-mediated activities in Table 1 (with activity ID's to be used in the subsequent tables in this chapter). Table 2 summarizes the essential information, including what smartphone-mediated activities were incorporated, of the twelve MLE lessons.

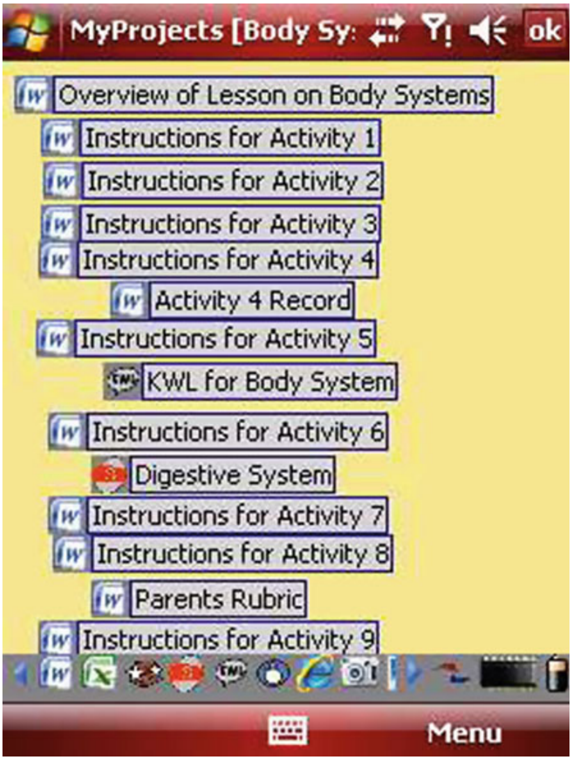


**Fig. 1** Screenshot of body systems. MLE unit

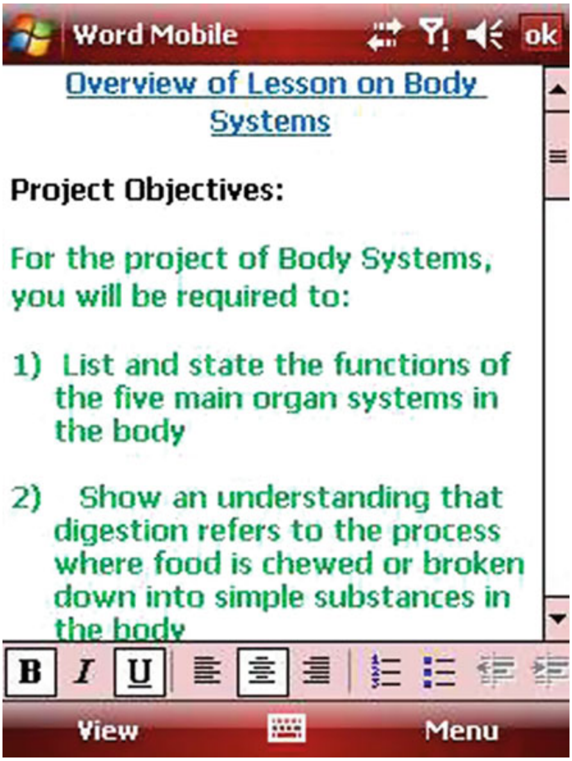


**Fig. 2** Overview of body systems lesson on the MLE as seen by the students

**Table 1** Types of mobile-assisted activities incorporated in the MLE curriculum

| Activity ID | Activity type | Mobile affordances |
|---|---|---|
| KWL | Self-regulation of learning progress | KWL |
| Anim | Animation creation | Sketchy |
| Ph | Photograph taking | Standard camera function |
| CM | Concept mapping | PiCoMap |
| Dsc | Online artifact sharing and discussion | Blog/Mobile Forum |
| Trp | Field trip | Video-, photograph- and note-taking tools |
| Exp | Scientific experiments | Video-, photograph- and note-taking tools |
| Par | Activities with parental involvement | Videos and other tools |
| Web | Web search and media playing | Internet Explorer, YouTube application |
| Col | In situ multimedia content creation and forum discussion | ColInq (with geo-tagged postings, each served as a discussion thread) |

**Table 2** List of MLE units designed for the mobilized curriculum (* denotes units that will be further evaluated below)

| Unit ID | Level and time period | Topic | Anim | KWL | Ph | CM | Dsc | Trp | Exp | Par | Web | Col |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P3-1 | February 2009 | Classification for living and non-living things | √ | | | | | | | | | |
| P3-2 | February and March 2009 | Classification of animals | √ | √ | | | | | | | | |
| P3-3 | March and April 2009 | Plant | √ | √ | √ | √ | | | | | | |
| P3-4 * | March and April 2009 | Plants and their parts | √ | √ | √ | √ | √ | | | | | |
| P3-5 | March and April 2009 | Fungi | √ | √ | √ | √ | | √ | | | | |
| P3-6 | April and May 2009 | Materials | √ | √ | √ | √ | | | √ | | | |
| P3-7 * | August and September 2009 | Body systems | √ | √ | | | | | | √ | √ | |
| P4-1 | January and February 2010 | Cycles | √ | √ | | | √ | √ | | | √ | |
| P4-2 | February and March 2010 | Matter | √ | √ | √ | | | | | | | |
| P4-3 | April 2010 | Light and shadow | | √ | | | | | √ | | | |
| P4-4 * | April and May 2010 | Heat and temperature | √ | √ | √ | | | | | | | |
| P4-5 * | July 2010 | Magnet | | √ | | √ | | | √ | √ | √ | √ |

## 3 Analytical Framework for Evaluating Curriculum Design

As stated before, the collaborative inquiry approach was adopted in the mobilized curriculum co-design not only for teachers' professional development but also for designing a curriculum that is rooted in the theoretical foundations of seamless learning, inquiry-based learning, and self-directed and collaborative learning. In co-designing the curriculum, we took into consideration the constraints posed by the context we worked with, such as the students' ability levels, resource limitations, the culture of the school establishment, and the national mandated science curriculum standards. Throughout the collaborative inquiry, the researchers refrained from dictating the design and were willing to listen to the teachers' voices to engage them in a process of co-design. As the BSCS 5E model is not inconsistent with our seamless and inquiry-based learning framework, it was retained to structure the lesson plans, as it is what the teachers are familiar with. The learning activities were substantially re-designed, steered by the six curriculum mobilization guidelines stated in the previous section. Taking into consideration the different individual topics and other factors, the actual learning activities varied from one lesson to another. For example, we introduced parental involvement for the “body system” topic and the Jigsaw collaborative approach for the “magnet” topic.

We searched for such mobile learning evaluation framework in the literature that we could use for evaluating our curriculum design. Two relevant papers were found: Dunleavy et al. (2007) and Sharples (2009). In his paper, Sharples (2009) outlined three major aspects to evaluate a mobile learning activity: usability, effectiveness, and satisfaction, but did not provide a concrete methodology to guide evaluation work. Conversely, Dunleavy et al. (2007) evaluated a variety of 1:1 classroom learning activities practiced by two middle schools using Bransford et al. (2000) four essential design principles of effective learning environments as their basis: learner-centered, knowledge-centered, assessment-centered, and community-centered. They presented their findings by categorizing and providing “scattered” examples of learning activities pertaining to each design principle. We argue that such an evaluation method is relatively coarse-grained and is more descriptive than analytic.

Instead, we adopted the framework of Frohberg et al. (2009) which was originally developed for their critical analysis of 102 mobile learning projects. Rooted in the task model for mobile learners (Sharples et al. 2007; Taylor et al. 2006) which was expanded from activity theory (Engeström 1987), Frohberg et al. derived a rubric-like method to evaluate six factors (namely the context, tools, control, communication, objective, and subject) of each reviewed project. Each factor has a scale of one to five, with the bigger value denoting being more desirable (as they require higher-order thinking) under normal circumstances. They used the framework to analyze the core pedagogical designs of individual projects. We will instead employ it to analyze the mobile learning components of our various MLE unit designs (see Table 3). This multidimensional framework is intended to capture the richness of the emerging mobile learning research arena and help one “to discover common ground and similarities, along with differences, inconsistencies or contradictions within the domain of mobile learning” (p. 308). We believe the framework would assist us in similar ways in comparing and contrasting the MLE lessons.

The six factors as proposed by Frohberg et al. (2009) were the outcome of their higher-level analysis of a more diversified set of mobile learning designs, which cannot be directly applied to analyze our MLE lessons without any adaptation. We will not assess our MLE units in the “subject” aspect as it is originally meant for characterizing the target learners (in particular, their prior knowledge levels, from novice to expert) of individual studies—our “subject” was always the same class of students (subject = 1, i.e., novice) and did not vary from lesson to lesson.

Another particular factor that we adapted is the tool factor, as some of the m-learning activities incorporated into our lesson units do not fit into any of the five

**Table 3** The evaluation framework of the MLE units of the SEAMLESS project (adapted from Frohberg et al. (2009), p. 312)

| Rating | Factor | | | | |
|---|---|---|---|---|---|
| | Context (relevancy of environment and learning issue) | Tools (pedagogical role of tools) | Control | Communication (social setting) | Object(ive) (level) |
| 1 | Independent context | Content delivery | Full teacher control | Isolated learners | Know |
| 2 | Formalized context | Interaction for motivation and control | Mainly teacher control | Loose coupling | Comprehend |
| 3 | -NA- | Guided reflection | Scaffolded | Tight coupling | Apply |
| 4 | Physical context | Reflective data collection | Mainly learner control | Communication within group | Analyze |
| 5 | Socializing context | Content construction | Full learner control | Cooperation | Synthesize and evaluate |

types of pedagogical roles that the factor originally describes. In essence, Frohberg et al. way of distinguishing the pedagogical roles was relatively physical context-oriented, where "tools = 1 and 2" are referring to learning activities unrelated to the physical context, while "tools = 3, 4, and 5" are activities situated in the physical environment, which essentially overlaps with "context = 4 (physical context)." We re-scoped the last three roles by generalizing them to include content-based or cyberspace-based activities as long as they either serve "guided reflection" (e.g., KWL activities [scaffolded individual reflection] and mobile forum [reflection triggered by peer negotiation of meaning]), "reflective data collection" (e.g., Internet search of data or information to assist subsequent learning activities), or "content creation" (e.g., creation of Sketchy animations).

## 4 Analysis of MLE Units and Lessons

In the next two sections, we will present and evaluate four of the MLE units that we co-designed with the teachers. The selected units demonstrate the diversity in the range of mobilized learning activities and illuminate our overall curriculum design both in terms of the content to cover and the inquiry/seamless learning skills to foster in the students. The selected units are: plants and their parts, and body systems (for year one); and heat and temperature, and interactions [magnet] (for year two). We will feature a summary of the flow of each unit in a figure, with smartphone-mediated activities in italics.

For the purpose of empirical study, we collected a variety set of data throughout the intervention period, namely (1) field notes, video, and audio recording of the MLE classes and taskforce meetings; (2) pre-, interim, and post-questionnaires; (3) pre-, interim, and post-interviews with six students with varied academic achievements and with the school management and participating teachers; (4) pre-, interim, and post-tests; (5) students' paper-and-pen-based and digital artifacts; (6) student–student and teacher–student online interactions; (7) students' school examination results. As the focus of this chapter is on implementation research with an emphasis on the evaluation of MLE unit design, we will not go into detailed analysis of student learning processes and outcomes which have been reported elsewhere (Looi et al. 2011; Looi et al. 2015). Rather, we will focus on analyzing the design as well as narrating some key findings in the MLE unit enactment with the aid of examples of student work.

## *4.1 MLE Curriculum: Year 1 (Primary 3)*

### 4.1.1 Brief Description of Units P3-1 and P3-2: Progressive Introduction to Mobile-Assisted Seamless Learning

In Unit P3-1 (classification of living and non-living things), we adhered to the 5E model learning flow but confined the learning to within the classroom. We started with a simple use of the smartphone (to create simple animations with Sketchy). The students were trained in using and handling the phones in the midst of Unit P3-1. However, it was not until Unit P3-2 where students were given the chance for the first time to bring their phones home over two weekends to carry out some designated activities (see below), and they were instructed to return the phones to the school on subsequent Mondays. At this early stage, the highly constrained access to the phones became a teaser to warm the students up toward future student-centered learning. It was also part of the enculturation process for the teachers in changing her instructional approaches. As the students became familiar with using handling their phones beyond the school compound during the first two weekends, they retained the handhelds 24 $\times$ 7 till the end of the two-year program.

This unit started off with a relatively conventional classroom session where the teacher led a discussion on classification of animals using a PowerPoint presentation and a Web site. She then tasked each student to fill in his or her KWL on the smartphone for the first time at home. The KWL activity was intended to provide a means to scaffold them in setting and reflecting upon their learning goals throughout their seamless learning experience (with the interplay of formal and informal settings) in this unit. The students also used the smartphone to create Sketchy animations to demonstrate their prior understanding of the unique characteristics of individual animal categories. They were asked to update their Sketchy animations as the lessons developed and as they developed their understanding of the categorization of animals. Through GoManage, the teacher was able to progressively monitor the students' progress and artifacts. As a form of formative assessment, selected student artifacts from all these of smartphone-mediated activities were presented and discussed in the class at different points of time.

At this early stage of the two-year intervention, the handhelds were used for note taking and for students' representation of their ideas. In particular, the Sketchy application afforded them the generation of animated artifacts that was not possible on paper. Such animations have the affordance of making the students' thinking and creating process visible to the teacher. This enabled the teacher to check the students' understanding and to intervene, when necessary, in the students' knowledge construction processes. Still, in essence, the affordances of personalization and mobility had not yet been prominently exploited. The overall design of this lesson was largely oriented toward textbook content rather than toward the students' day-to-day living context. It was a gentle start to get the students acquainted with the devices as their "learning hub" and not to rush the students into more advanced m-learning activities. More subtly, the lesson empowered students with content creation and in the absence of prescribed textbook and activity books, students could practice constructing their own knowledge. The students also swapped their phones with their adjacent peers in the class to view and comment on each other's work.

#### 4.1.2 Evaluation of Unit P3-4: Plants and Their Parts—Enculturating Learners to Generate Artifacts

Prior to this unit, students learned about the basic characteristics of plants in Unit P3-3 (Plants). Apart from maintaining their KWL pertaining to the unit, they were required to take pictures of different edible plant parts (e.g., potato (stem), carrot (root), and tomato (fruit)) at home. This was the first time the teacher tasked the students to extend their seamless learning experiences into their daily lives, i.e., a preliminary attempt to bring contextual/authentic elements into their learning. This helps students to be aware that plants are not just the trees and bushes they see along the road, but can also take the form of vegetables they are eating. The teacher then facilitated a sharing, discussion, and classification exercise using the photographs taken and assisted the students in identifying misconceptions such as the classification of the potato as being the fruit of the plant. Another "first time" for the student was to create a PiCoMap to organize their conceptual understanding from what they collated from their research.

Unit P3-4 extends the preceding unit with the aim of deepening the learning of plant parts as well as understanding the concept of "diversity." Figure 3 depicts the learning flow design of Unit P3-4. The students' inquiry process started with them conducting Internet research to find out the functionalities of various parts of plants. The italicized descriptions of activities in Fig. 3 (as well as in Figs. 6, 7, and 9) denote activities that utilize the smartphones. Figure 4 shows a student searching and identifying a relevant educational video clip on the web. She watched it and then filled in a teacher-supplied table. After they had gained some basic understanding, they were encouraged to take pictures of different parts of the plants they encountered at their neighborhood. We consider such an activity form a means of

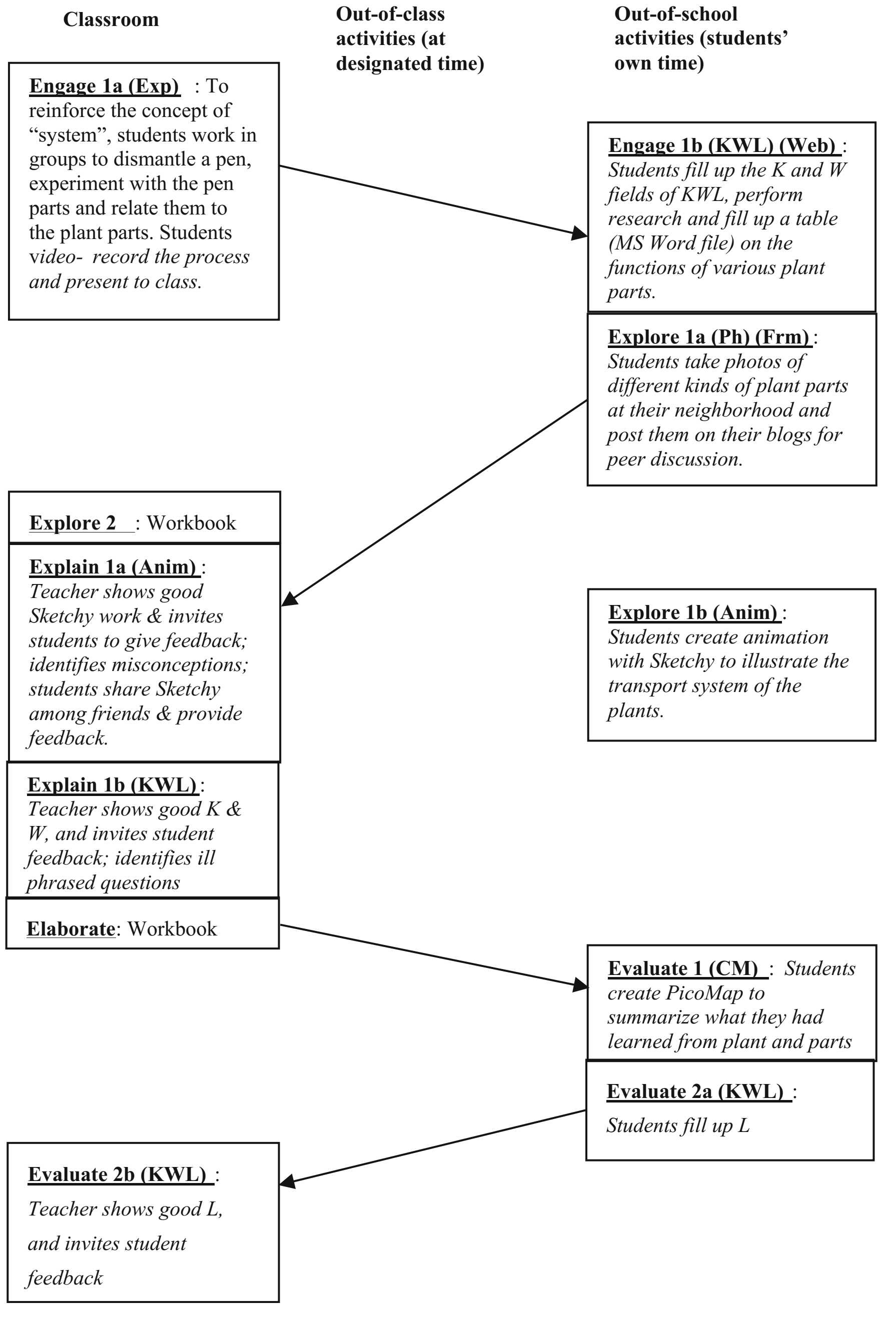


**Fig. 3** The flow of Unit P3-4: "Plant and their parts"

**Fig. 4** A student conducting Internet research on parts of plants

triggering their observational and reflective habits of mind during their daily encounters, which can lead them to associate their findings in such informal learning spaces with what they have learned in their formal classes. The students then posted the photographs onto their blogs to trigger peer discussions for comparing different types of roots, leaves, and stems.

Table 4 depicts our evaluation of the mobile-assisted learning activities in this lesson. KWL, animation creation, and concept mapping are situated in the independent context (context = 1, as students carried out these activities at their own time) with scaffolded control (control = 3). How do we characterize the communication aspect of the activities? It can be attributed to "isolated learners" (communication = 1) because the students first carried out the activities individually with their handhelds, but it may also be "cooperation" (=5) because the entire class was then involved in discussing their artifacts arising from the three activities ("communication or collaborative learning *over*, not *through*, the device"). We decided to rate them with 5 as we believe that the activity designs should be assessed as a whole rather than in terms of when and how the mobile devices were used.

**Table 4** Evaluation of the mobile-assisted activities in Unit P3-4

| Activities | Context | Tool | Control | Communication | Objective |
|---|---|---|---|---|---|
| *KWL* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *Ph* | 4 (physical) | 4 (reflective data collection) | 4 (mainly learner control) | 5 (cooperation) | 3 (apply) |
| *Anim* | 1 (independent) | 5 (content construction) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *Dsc* | 5 (socializing) | 3 (guided reflection) | 4 (mainly learner control) | 5 (cooperation) | 4 (analysis) |
| *CM* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 4 (analysis) |

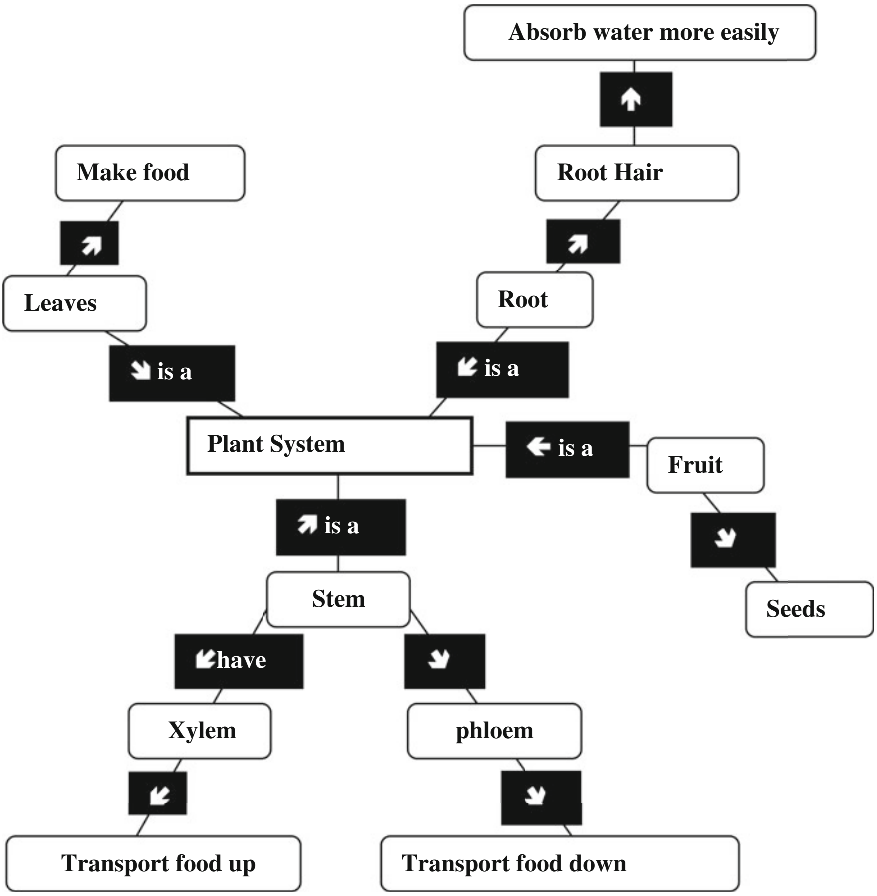


**Fig. 5** A student's PiCoMap created by the end of Unit P3-4

The photograph-taking activity marked a major departure from the relatively formally structured learning designs in the previous lessons. Most of the teacher-facilitated, episodic learning trails reported in the literature tended to deploy structured learning activity designs and were situated within a relatively controlled physical environment (e.g., Kamarainen et al. 2013; Shih et al. 2010; Shear et al. 2014; Spikol and Milrad 2008). Such trials took place within a designated time slot and location and often with teacher pre-specified objects that the students need to search for and identify, or even with a relatively linear physical path for the students to move about. Instead, our photograph-taking activity gave students greater control (control = 4) in the sense that it was a learning experience that was genuinely blended into their daily lives. This was achieved by carrying out reflective data collection (tool = 4) that enabled them to apply (objective = 3) their classroom-learned knowledge of plant parts to observe perhaps unfamiliar plants that they encounter, in this virtually borderless physical world (context = 4), and appropriating their encounters to mediate their learning (Wong et al. 2012).

The follow-up blog-based sharing and discussion was a meaningful post-activity after photograph taking. Wong et al. (2010) cite several similar m-learning studies that required learners to take photographs in their daily life and argue that such learning designs treat the learner-created content as the end, which would then become static learning materials accessible by their peers. They advocate using such authentic materials as the means to extend such m-learning activities from personal to social meaning making, i.e., to make use of the stated learner artifacts to mediate subsequent discussions. The photograph-taking–sharing–discussion subprocess in P3-4 is congruent with this principle. It is therefore a mainly learner controlled (control = 4), cooperative (communication = 5), analytical (objective = 4), and guided-reflective (tool = 3) activity that is situated in the socializing context (context = 5). The students' learning gains through these seamless learning activities were evident in the PiCoMap artifacts that they created by the end of the unit. Figure 5 depicts one such student artifact that demonstrates her good understanding of the unit topic.

While some students chose to show their understanding through PiCoMap, others made use of Sketchy. This was one of the MLE lesson designs that provide a showcase of multilearning and assessment modalities.

#### 4.1.3 Brief Description of P3-5 and P3-6—Magnifying Authentic Learning

The design of the next two units (P3-5 and P3-6) employed similar learning flows. Both lessons incorporated the KWL activity, photograph taking, online discussion, Sketchy animation creation, and concept mapping. In particular, for P3-5 (fungi), we facilitated the "fungi detective" activity by getting the students to identify and take photographs of fungi in their living environments found at home and in the neighborhoods. The teacher then flashed selected photographs and facilitated a classroom discussion to help the students see that fungi could be both useful and harmful. Likewise, in P3-6 (materials), the students were required to identify and take photographs of "objects that are strong, soft, float on water and are not transparent." They then created Sketchy animations to label the material and indicate the purpose of the object.

In addition, we arranged for the first field trip to a probiotic drink factory in the midst of P3-5 for them to learn about the presence of good bacteria in a drink commonly known to them and how the bacteria travel through their digestive system. In the trip, a learning connection was made between the concepts of bacteria being a living microorganism and how the organs in the digestive system function in a human body system. They might also relate this to their experiences of stomach disorders when they eat contaminated food.

#### 4.1.4 Evaluation of Unit P3-7: The Body System—Bringing in Parental Involvement

One important principle in learning activity design is to incorporate the right activities to the right topic to facilitate student learning, by taking the nature of the topic into consideration. Much as we saw the potential impact to student learning in daily photograph-taking activities that we facilitated in the last three MLE units, it was not necessarily suitable for the learning of all science topics. For Unit P3-7 on the topic of "the body system," instead of stimulating the students to actively observe and make sense of their surroundings, the students could learn the topic by making sense of their own bodies.

In this regard, we designed for the involvement of the people who were closest to the students—their parents—in this MLE unit. Apart from the usual web research, KWL, Sketchy, and group video-making activities, parents were involved in two stages of the learning flow. First, the parents used the handhelds to video record the students carrying out the chew and swallow experiment, which was more of a logistic arrangement (since it was difficult for the students to video record their own actions) as well as giving parents the first "taste" of being involved in their children's MLE learning process. Second, they participated in the culminating activity of the lesson, "teach-your-parents." The students were tasked to ask the parents what they knew about the digestive system and to identify gaps in their parents' knowledge. They had to teach the parents what they thought the parents did not know and to interview their parents again to check their understanding. All the parent–child interactions were video- or voice recorded with the smartphone. Back in the classroom, each student shared the recording with a peer by swapping their smartphone, and together they discussed and reflected on their own understanding of the digestive system. In turn, misconceptions were surfaced and challenged. A dissection of a student's conversation with a teacher in the classroom is presented below.

S(tudent): I taught my father to do the digestion process but I didn't do the digestion system whole thing.
T(eacher): Ok… why
S: I say wrong to my father
T: What did you say to your father?
S: I say to my father... I told him that for my homework I need to do the digestion… digestive process. Then he said ok.
T: Ah…huh… so what did you teach you father?
S: I taught my father that the food goes in the gullet…eh… the mouth… then chew… then the saliva mix… then through the gullet. Gullet will relax and contract to let the food go into the stomach. Then the stomach will add digestive juices and then the food will go into the small intestine. The food digestion ends there.
T: So… what should happen?
S: To the anus.
T: Before anus?
S: Large intestine?
T: Ok, what happens in the small intestine?
S: The food is digested.
T: Ok, then what happens in the small intestine?
S: I don't know.
T: Jerome (Another student), do you know?
S: (Shakes his head but later he said) absorb nutrients.
T: Very good. Did you father mention that nutrients are absorbed in the small intestines?
S: Yes. After the food go into the small intestine, it will go through the large intestine.
T: What kind of food goes into the large intestine?
S: Undigested food.

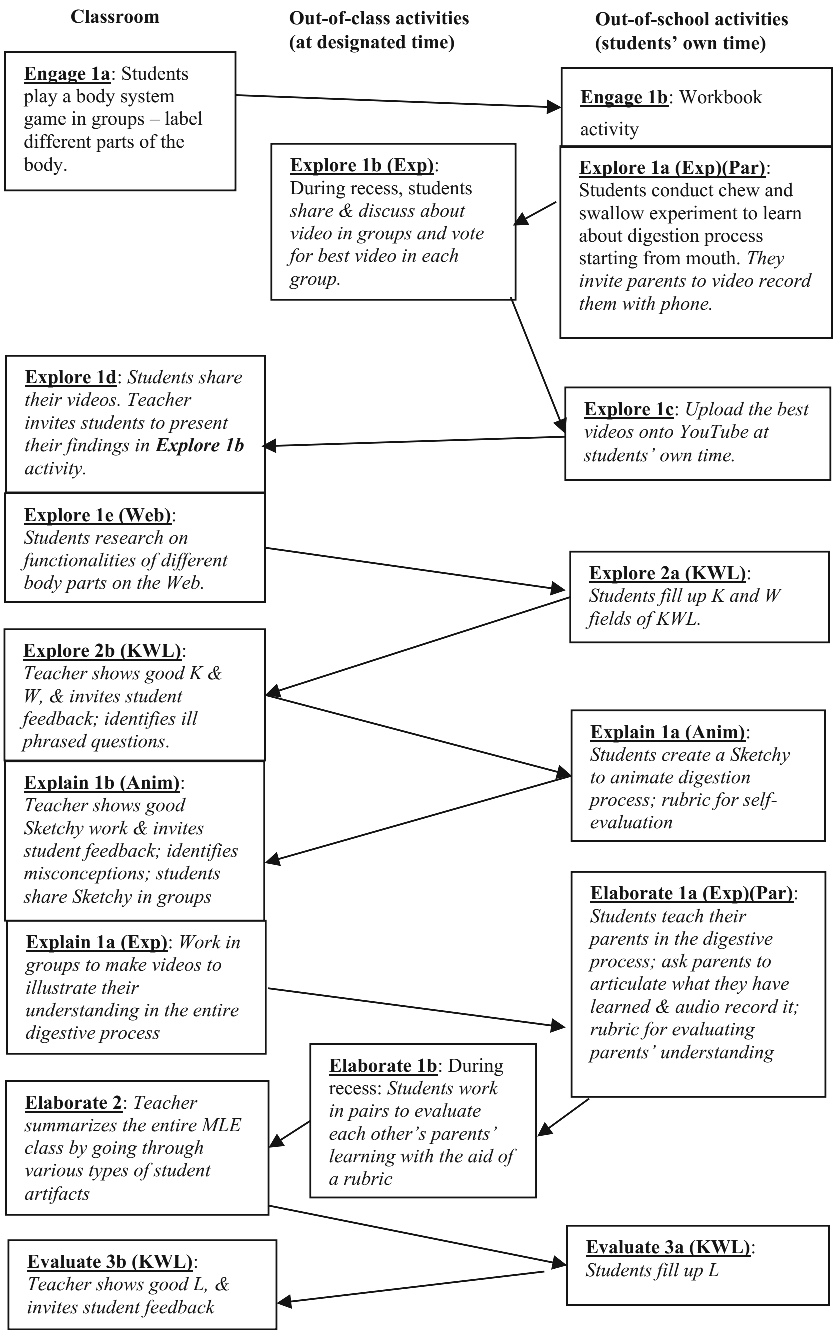


**Fig. 6** The flow of Unit P3-7: "The body systems"

**Table 5** Evaluation of the mobile-assisted activities in Unit P3-7

| Activities | Context | Tool | Control | Communication | Objective |
|---|---|---|---|---|---|
| *(Exp)(Par)* Chew and swallow experiment with parents taking videos; sharing and uploading videos | 1 (independent) | 2 (interaction for motivation and control) | 2 (mainly teacher control) | 5 (cooperation) | 2 (comprehend) |
| *(Web)* Research on body parts | 2 (formalized) | 4 (reflective data collection) | 2 (mainly teacher control) | 1 (isolated learner) | 2 (comprehend) |
| *(KWL)* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *(Anim) Sketchy* | 1 (independent) | 5 (content construction) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *(Exp)* Group video making to illustrate digestive process | 2 (formalized) | 5 (content construction) | 3 (scaffolded) | 4 (group) | 2 (comprehend) |
| *(Exp)(Par)* Teach parents and video or audio record their articulations; bring recording back for peer evaluations | 5 (socializing) | 3 (guided reflection) | 3 (scaffolded) | 3 (tight couples) | 2 (comprehend) |

The background of this interview was that the student Larry (a pseudonym) approached a researcher and defended his father when his peer said that his father was not able explain the whole digestive system well. He explained that he did not teach his father the functions of the large intestine and rectum because he thought he only had to cover digestion. Since digestion stops at the small intestine, he did not include the other two organs. When Larry watched the video recording of his father, he realized that he should also include the large intestine and rectum so as to make the digestion system complete. In this process, his understanding for digestive system was refined. Learning became a meaningful process, not just about rote memory.

Figure 6 and Table 5 depict the learning flow design and our evaluation of the design of Lesson P3-4, respectively.

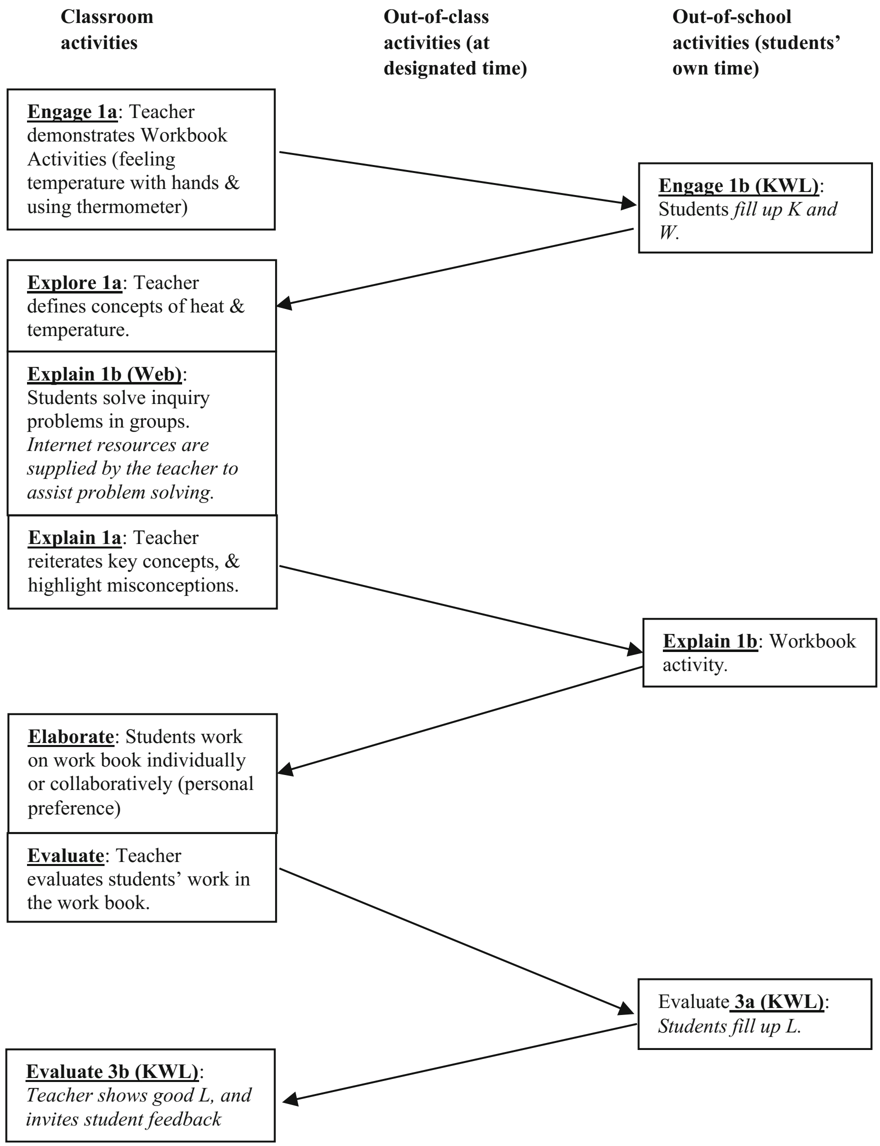


**Fig. 7** The flow of Unit P4-4: "Heat and temperature"

As listed in Table 4, we have consistently rated some of the now-standard MLE activities (KWL, Sketchy) as in previous lessons (e.g., context = 1, tool = 3 or 5, control = 2 or 3, communication = 4 or 5, objective = 2). One variation is the individual web search activity. We characterized it as "reflective data collection" (4) for its "tool" factor, which is different from its original definition in Frohberg

**Table 6** Evaluation of the mobile-assisted activities in Unit P4-4

| Activities | Context | Tool | Control | Communication | Objective |
|---|---|---|---|---|---|
| *(KWL)* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *(Web)* Student groups solve problem with the aid of teacher-supplied web resources | 2 (formalized) | 1 (content delivery) | 2 (mainly teacher control) | 4 (group) | 3 (apply) |

et al.'s framework—their "data collection" is specifically referring to collecting data in the physical reality, such as measuring temperature or photograph taking, while we consider web search as another form of data collection. Indeed, this form of data collection is not so much an exploitation of the handhelds' mobility in the physical reality. Still, it was an integral part of the MLE lesson that took place before KWL and perhaps helped the students to shape their "K" and "W."

The "teach-your-parents" activity was a greater departure from our previous MLE lesson design, as it pushed the context boundary from formalized to socializing (context = 5). The socializing context of mobile learning refers to social learning that either involves people within or beyond the students' class community—in our case, it is the student family. We have also characterized its communication mode as tight coupling (3) where it actually involves two coupling—student–parent communication at home for students' "learning by teaching" and in-class student–student communication for peer evaluation on the learning outcomes of each other's parent.

### 4.1.5 The School Management's Feedback at the End of Our Year 1 Intervention

By the end of our year 1 intervention with seven MLE units being enacted, we analyzed the summative science examination scores of all the classes. Our analysis showed that the experimental class students performed better in their semestral science examination as compared to five other mixed-ability classes in the same level who undertook the traditional science lessons (see: (Looi et al. 2011) for more details).

Nevertheless, during the review meetings, the Head of Science Department raised her concern that certain prescribed activities in the Primary 3 activity book, such as assignments with examination-style questions, were not incorporated into the MLE units. She expressed her view that the parents would expect these activities to be completed by the students. The teachers in the task force also shared that, from their past experiences, they did not have enough curriculum time to complete the Primary 4 prescribed activities. They were concerned that if the activities were not covered like the traditional classroom, their students might lack the practice for similar questions in the examinations. There was not enough time to run the mobilized curriculum lessons and such school prescribed activities in parallel. To address the school management and teachers' concerns, we decided to incorporate these workbook activities into the Primary 4 MLE design. This, in turn, restricted the design of the Primary 4 MLE units, and as a result, a more structured and summative-assessment-oriented Primary 4 MLE was produced.

## *4.2 MLE Curriculum: Year 2 (Primary 4)*

### 4.2.1 Brief Description of Unit P4-1: Cycles

In designing this first MLE unit for Year 2, we incorporated the highly structured workbook activities as a response to the school management's concerns and the teachers' perception of the time constraint. Still, we injected three new elements, namely a farm trip, the growth of spinach using hydroponics method and rearing of caterpillars, and the mobile forum, to the learning flow design to make it as lively and contextualized as possible. We facilitated a farm trip for the students to investigate how various types of vegetables were grown using hydroponics. There was also a butterfly enclosure for the students to observe a variety of butterflies and their eggs, caterpillars, and chrysalises in the midst of the flowers and plants. With their phones, the students took photographs and videos of any object that raised their interest, and took audio notes of any ideas that came into their mind with the voice recording feature, as well as answered a series of science- and mathematics-related questions. Using the farm physical environment as a backdrop, they were also given a problem-solving activity and were tasked to improve the composition which they had planned in school. Many students went home with seeds which they can cultivate using hydroponics method and caterpillars which they can rear in a special container provided by the farm. In turn, they observed and recorded the life cycles. They consolidated the collected data in their Sketchy presentations and brought the spinach back to the class for sale to the teachers and other students in the school. We then launched the mobile forum for students to extend their social meaning making and collective reflection on the topic beyond the course of the unit.

### 4.2.2 Evaluation of Unit P4-4: Heat and Temperature—Sidelining Mobile Learning Activities

We picked Unit P4-4 as an exemplary unit of P4-2, P4-3, and P4-4 to analyze. This set of units reflects how we addressed the school management's concerns that they raised at the end of the previous year by designing learning activities that focus more on getting students to answer workbook-type questions correctly than encouraging seamless, inquiry learning. In these units, we still facilitated the students to conduct KWL, Sketchy, and/or concept mapping activities (different combinations of activities in different units). However, these mobilized activities had been sidelined. Our six guidelines for mobilized curriculum design were almost abandoned. For example, we arranged for workbook activities to conclude each of these lessons, unlike that in our previous design where the more open-ended, personalized concept mapping or the "L" of KWL was carried out to summarize or synthesize student learning. Group inquiry activities were implemented in these three units, but they relied less on the smartphone (mostly used for web information search within groups).

Figure 7 and Table 6 depict the learning flow design and our evaluation of the design of Unit P4-4, respectively.

From Table 6, our ratings on the (only) two mobilized activities in Unit P4-4 seem to be similar to that of our P3 lesson designs. By reviewing the overall lesson design, however, we recognize how our original goals for the curriculum design exercise, in particular, the nurturing of seamless learning and inquiry learning with a sensible exploitation of the technological affordances were debilitated.

As a result of sidelining mobile learning activities, through the quality and quantity of KWL attempted (see: Sha et al. 2012), we observed that in comparison with the lessons where mobilized activities were central, students' motivation in learning plummeted in unit P4-4. We compared the KWL attempted by the students in P4-4 and P4-5 (see the next section—with a more dynamic learning process than P4-4). It was observed that other than the increase in amount of items reflected in P4-5 than in P4-4, the students reflected more upon their learning more in two major aspects. Firstly, the students asked themselves authentic questions that were not found in the textbook and experiences that were not part of the lesson in class. Secondly, the students reflected beyond discussion points that arose during class activities. Examples of the KWL can be seen in Fig. 8.

#### 4.2.3 Unit P4-5 Magnet—Back to a More Holistic Seamless Learning Experience

The design of Lesson P4-5 marked the return of our more dynamic and seamless learning design that we practiced in our previous year's (Primary 3) mobilized units. By incorporating a new Web 2.0 tool, Collnq, students can create artifacts (like taking photographs or videos) on the fly with geo-tagging and add annotations which can be shared and built upon by other students. We brought back out-of-school, personalized inquiry activities by getting the students to experiment using magnets to test on different objects that they encounter in their daily lives, take photographs or videos, or figure out inquiry questions, and post these artifacts onto Collnq for sharing and discussions. Back in the class, the teacher made use of selected student artifacts posted on Collnq to get the class to infer magnetic and non-magnetic objects. The students were also allowed to bring their magnet making experiments (and even "magic shows") home so that they could work with their

| KWL from Unit P4-4 | KWL from Unit P4-5 |
|---|---|
| **I Know**<br>I know that heat can be transfer from one substance to another<br>I know that heat can be used at home or at industries<br>I know that there are many sources of heat<br>I know that hat can cause to change state of matter<br>I know that heat is a form of energy<br>I know that heat flow from a hotter object to a colder object<br>I know that heat cannot be seen but can be felt<br>I know that some metals like iron and steel are good conductor of heat<br>I know that some materials like rubber are insulators of heat<br>**I Wonder**<br>**I Learned** | **I Know**<br>I know that magnets can be used at home and at factories<br>I know that magnets have a north and south pole<br>I know that unlike poles of the magnet attracts<br>I know that like poles of the magnets would repel<br>I know that can attract to magnetic metals also<br>I know that magnets would point towards the north-south direction when it is allowed to swing freely<br>I know that some electrical devices contain magnets<br>**I Wonder**<br>**I Learned** |
| **I Know**<br>**I Wonder**<br>**I Learned**<br>Heat energy is a form of energy which transfers among particles in a substance by means of kinetic energy of those particles, In other words, under kinetic theory, the heat is transferred by particles bouncing into each other. | **I Know**<br>Magnets attract magnetic materials like iron and steel<br>Unlike poles attract/like poles repel<br>Magnet and a magnetic object attract<br>A temporary magnet and a magnet object will attract<br>**I Wonder**<br>What is the difference that you observe between the fishing rod and the button magnet?<br>Is stainless steel magnetic?<br>Coloured drawing board? Why does the colour iron fillings will not jumbled together?<br>Is titanium magnetic?<br>**I Learned**<br>Magnet are usually in places that you don't think about<br>Stainless steel are not magnetic |

**Fig. 8** Example of student's KWL

parents. Their experiments were recorded and brought back to the classroom for further discussion.

Figure 9 and Table 7 depict the learning flow design and our evaluation of the design of Unit P4-4, respectively.

In P4-5, the use of the mobile phones reverted to a personal tool for research and data collection. The focus is on construction of knowledge and extension of classroom activities. The class activities evoked students' curiosity and enabled them to further challenge their understanding of the underlying concepts of how a magnet works. Instead of assigning students inquiry questions like the lesson designs in P4-1 to P4-4 and mandating the way the questions should be answered, the students were tasked to find out how they could design and make magnets.

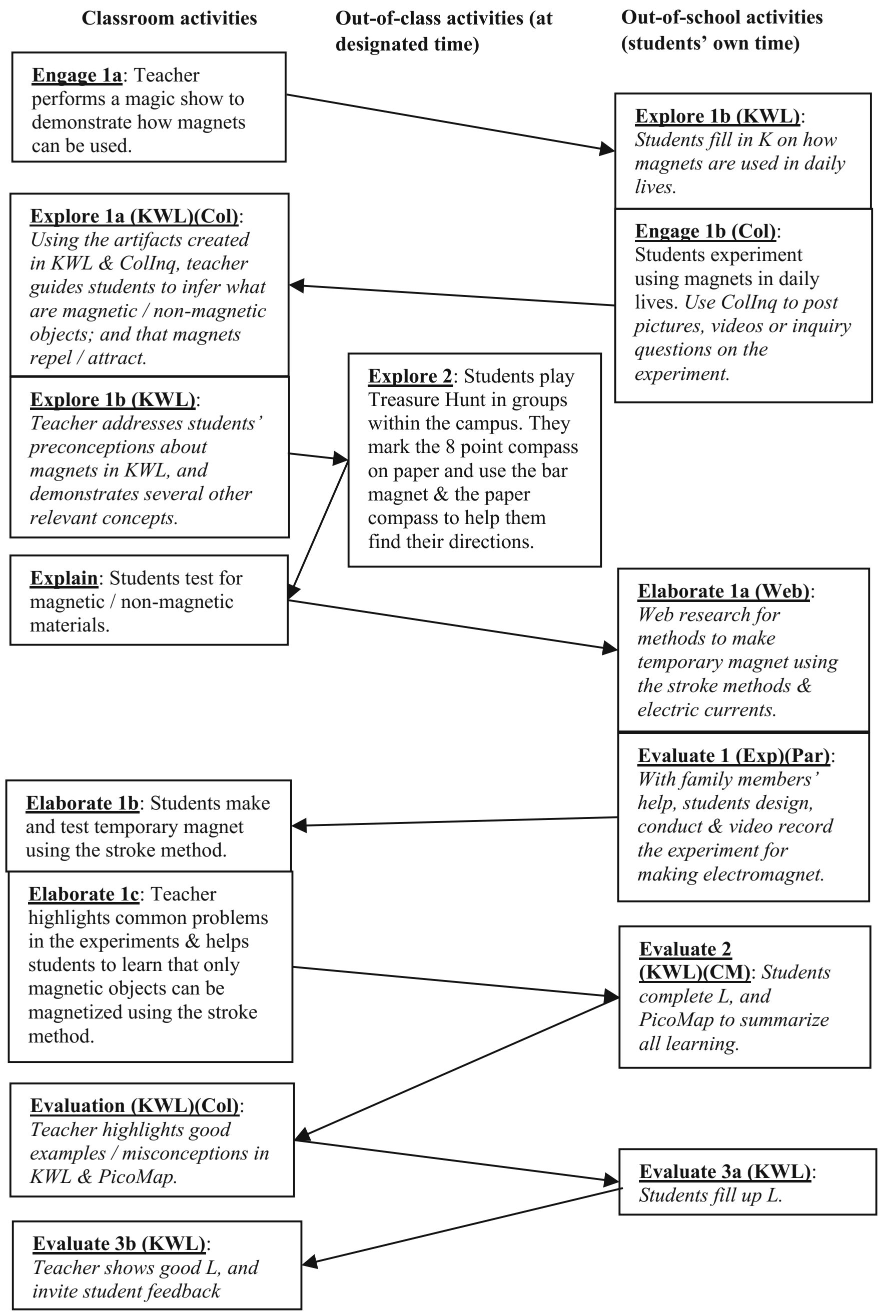


**Fig. 9** The flow of Unit P4-5: "Magnet"

Figure 10 shows an example of students' independent research for the activity. Although the students were given the same task, they were free to choose how they wanted to complete the activity. Making choices available in the design encouraged students to explore and extend their learning beyond the scope of textbooks and workbooks.

## 5 Discussion

To design a MLE curriculum to enhance, if not replace, the existing curriculum, the required changes encompass threefolded dimensions: curriculum (curricular learning goals), pedagogy, and technology. As the contextual environment (such as the national curriculum and assessment modes) could not be changed within the duration of the intervention study, the emphasis was on re-designing the existing curriculum and facilitating a gradual techno-pedagogical shift. In this way, teachers who are risk-averse might be more willing to take up the curricular innovation. The approach is to strive for evolutions in the classroom practices and the students' habits of mind in learning, rather than a revolution. If a revolution is to be insisted, our re-designed curriculum might not be able to go beyond the clinical stage of the research since the school leaders may refuse to change the existing science teaching practices drastically to accommodate it.

**Table 7** Evaluation of the mobile-assisted activities in Unit P4-5

| Activities | Context | Tool | Control | Communication | Objective |
|---|---|---|---|---|---|
| *(KWL)* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *(Exp)(Col)* Experiment using magnets in daily lives (use CollInq to share photographs, videos or inquiry questions) | 4 (physical) | 4 (reflective data collection) | 4 (mainly learner control) | 5 (cooperation) | 3 (apply) |
| *(Web)* Web research for methods to make temporary magnet | 1 (independent) | 4 (reflective data collection) | 2 (mainly teacher control) | 1 (isolated learner) | 3 (apply) |
| *(Exp)* Conduct and video record the experiment for making electromagnet, and the performance with the use of magnet | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 2 (comprehend) |
| *(CM)* | 1 (independent) | 3 (guided reflection) | 3 (scaffolded) | 5 (cooperation) | 4 (analysis) |

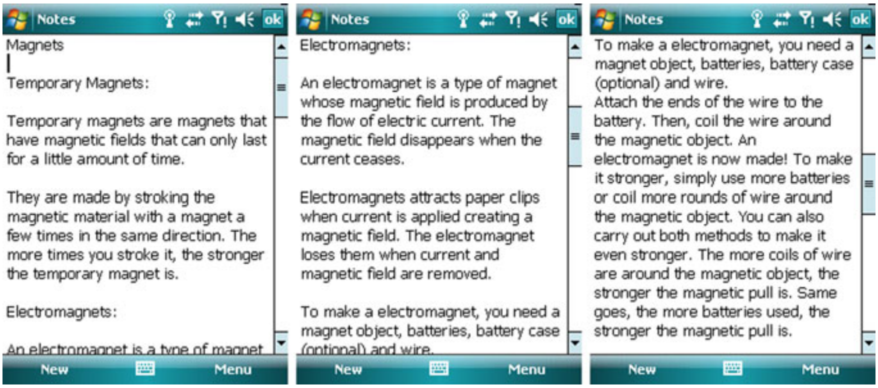


**Fig. 10** Student's independent research on magnets

The intervention project was driven by the key notion of seamless learning, foregrounded by authentic, self-directed, and collaborative inquiry learning in the science curriculum re-design. While the science curriculum design adopts the BSCS 5E model in which the teachers are familiar with, we retrospectively observe an emergent pattern of systematically introducing various types of MLE learning activities to nurture dispositions in the cross-context student learning across our design-enactment-reflection-refinement cycles of MLE curriculum development. This was a result of the taskforce's continuous dialogues and reflections on the curriculum design that integrates subject content, the technological affordances, and the progression of student learning. The parallel progression of researchers' literature review, research design, and formative evaluation of research and researcher-teacher co-design, enactment, and formative evaluation of curriculum development ensured the timely responses to the day-to-day demands from both teaching and research.

The students started their learning journey by creating their own conceptual representations with the smartphone (Sketchy animations from Unit P3-1 onward). This was followed by reinforcing students' self-regulation in science learning (KWL), from Unit P3-2 onward. Then, in Unit P3-3, the intervention introduced the out-of-school, highly open-ended photograph-taking activity where students needed to be observant at their daily encounters and associate those with their learned knowledge in the class, thus achieving seamless learning. In addition, concept mapping activities (with PiCoMap) were adopted as a means of concluding each MLE unit by getting the students to consolidate their learning. Unit P3-5 saw the enactment of a cross-topic field trip to study how the relatively popular (within the m-learning community) "social reflective data collection" approach could fit into our MLE curriculum. In Unit P3-7, student–parent interactions in the learning design were introduced and incorporated into the approaches of "learning by teaching" and peer reviews (of each other's parent) to reinforce students' social learning and reflective learning. Unit P4-1 brought in another field trip and facilitated follow-up activities such as water spinach and caterpillar growing, and mobile forum discussions so that the students would carry on deepening and internalizing the situated knowledge that they picked up at the field trip. These activities provide the experiential authentic experiences of students as they are learning continuously across these various settings.

Indeed, through these multifactor evaluations of our learning design, the approach of designing for "mobile devices as learning hubs" for individual students is re-affirmed. Whereas the recent m-learning community has been carrying a popular view that m-learning designs that undermine the mobility affordance (e.g., for situated, context-aware learning) of the mobile devices are inferior designs, our MLE curriculum design that focuses more on exploiting the personalization affordances of the devices has its value and significance—indeed, from a seamless learner's point of view, the individual herself is the invariant and there needs to be a sense of seamlessness in switching contexts between learning activities (Looi et al. 2013; Wong and Looi 2011). Our notion of "learning hub" advocates the assimilation of mobile devices into individual students' everyday life experiences by integrating various personal (and collaborative) learning tools, resources, and artifacts at one place. With systematic learning design to nurture their self-directed learning habit, such a "learning hub" would mediate individual students' complete seamless learning process.

Nevertheless, the turning point was at the end of our first-year intervention, when the school management talked us to make our second-year MLE curriculum design more structured and workbook-driven—to them, it was important to ensure a certain level of coherence in the lesson flow. We practiced what they asked for in Units P4-2, P4-3, and P4-4, and sacrificed the seamlessness in the design.

Subsequently, we observed the students' motivational level in the MLE curriculum being dropped in the second year. We deduced three possible reasons behind the decline—the change of the learning design, the decline of their handhelds' performance (the hardware wore off and the Windows OS slowed down), and the diminishing of the novelty effect in the technology. However, as we observed the students' enthusiasm returned during Unit P4-5 where we brought back almost all types of mobile-assisted learning activities grounded in seamless learning option, it is a plausible inference that the liveliness of the learning design plays an important part in motivating student learning, perhaps more so than the other two factors.

The two-year implementation of the transformed science curriculum for a class for over two school years led to positive learning gains for the students and changes in the teacher's capacity to teach such a curriculum (Looi et al. 2011). Because of such outcomes, the school decided to scale up the mobilized lessons from one class to all classes in the grade levels of 3 and 4. Thus, the school administration in consultation with parents of the new classes has taken on ownership to continue the seamless learning pedagogy. The participating teachers from the two experimental classes have become curriculum leaders to develop other teachers' abilities in adopting and adapting the seamless learning practice. Our mobilized curriculum and teacher guidebook also become part of the infrastructure for sustaining the efforts.

The subsequent research efforts focus on adapting and “ruggedizing” the innovation for sustainability to retain substantial efficacy in diverse contexts of all classes in the level (Looi et al. 2015). The MLE curriculum was designed for a mixed-achievement class. Scaling up involves customization of the MLE curriculum for students who are higher ability and for students who are lower ability. Our research also developed an effective model for larger-scale teachers’ professional development for the enactment of MLE curriculum (Looi et al. 2016).

## 6 Conclusion

To achieve a genuine integration of 1:1, 24/7 m-learning into students’ daily lives, there is a need to revamp school-based curriculum and pedagogies to support sustained authentic learning and foster students’ skills of seamless learning, so that m-learning practices are not just about episodic interventions that may not result in long-term impacts on school practices and students’ habits of mind in learning (Wong et al. 2012). In this chapter, we have narrated our two years’ journey in curriculum mobilization, with the emphasis on evaluating the curriculum design, with valuable experiences gained in continuously improving our socio-techno-pedagogical framework of the seamless learning practice within the school ecology that it was situated in. The curriculum enables authentic learning for the students, learning that is seamlessly integrated or implanted into meaningful, situations that the students experience inside and outside of the classroom.

As a narration of the implementation research trajectory, this chapter describes the cycles of work in designing each curriculum unit iteratively and how the cultural norms and practices of the school posed constraints and challenges to the design and enactment of the curriculum. We use an analytic framework to evaluate selected curriculum units. In doing so, we hope to contribute to the literature by providing more detail on how to translate learning theories and integrate mobile technology affordances into sustainable practices in regard to curriculum development. We encourage more effort in such directions to allow researchers and practitioners to design more sustainable and scalable interventions for education change in schools.

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# Kaleidoscopic Course: The Concept, Design, and Implementation of the Flipped Classroom

**I-Ling Cheng, Sie Wai Chew and Nian-Shing Chen**

**Abstract** This chapter aims to contribute the concept, design, and implementation of the flipped classroom for pre-service and in-service teachers to run a flipped classroom. Two essential components, pre-recorded interactive video lectures and incorporating highly interactive learning activities, of flipped classroom are first identified. Then, the six types of classrooms are proposed including physical classroom, asynchronous cyber classroom, synchronous cyber classroom, mobile classroom, social classroom, and ubiquitous classroom. Each classroom can be interwoven with the two essential components in order to provide six different venues for students to learn a unit/lesson. In other words, the six types of classrooms are implemented to conduct/support versatile learning activities so as to maximize the flexibility of flipped classrooms. Except for physical classroom, the benefits of using other types of classrooms are cyber face to face, equal distance among all participants. The purpose of the two essential components and the six different types of classrooms is to provide more opportunities for student to learn a topic in depth in the flipped classroom. Additionally, a methodology containing four implementation stages is elaborated in this chapter to help teachers to conduct flipped classrooms. These four-stage methods are designing learning content, leading learning activity, guiding students with specific learning difficulties, and managing good learning atmosphere across multiple learning spaces. Each stage fully utilized the aforementioned two essential components and six types of classrooms. Feasible solutions addressing potential issues and challenges are also proposed in this chapter.

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**Keywords** The flipped classroom · Pre-recorded interactive video lectures · Highly interactive learning activities · Cyber face to face · Learning ownership

## 1 Introduction

The widespread development of computers and the internet has allowed teachers to successfully integrate technology into their classes in the past decades (Afshari et al. 2009; Buabeng-Andoh 2012; Dwyer et al. 1990; Ertmer et al. 2012; Hastie et al. 2010; Russell et al. 2003). The flipped classroom incorporates various learning technologies to diversely deliver learning content and activities both inside and outside of the classroom. These approaches may not be provided in the traditional classroom setting since the class time of teachers is swarmed with lecturing.

Students will not be able to learn a unit/course if they do not physically participate in the classroom, and they will not be able to learn that unit/course more than once within the classroom or after the class. Ash (2012) shows in "Educational Week" that the current teaching–learning model cannot help all kinds of students to learn after class, but the flipped classroom can assist individual students to learn after class. Additionally, the reason why teachers would like to keep teaching and learning in traditional physical classrooms is because they believe that the traditional way can provide students a chance to interactively learn with their teachers by having face-to-face contact. Nevertheless, the reality of the situation is that most students only sit in the classroom listening to a teacher's lectures without much interacting and communicating with that teacher. Also, some teachers are against virtual classrooms because they do not believe or think that students actually do learn the subject matter by themselves online. These reasons hinder students to cultivate twenty-first-century skills due to the limitations of conventional classrooms.

The flipped classroom attempts to solve these issues since it provides students an opportunity to preview the pre-recorded video lecture, take notes, and come with problems before a classroom session. Simultaneously, it requires teachers to prepare highly interactive learning activities for a classroom to support students to learn a unit/course before and after class. Instead of lecturing in the classroom, teachers work on designing and conducting interactive learning activities by using collaborative learning, authentic learning, situated learning, and/or problem-solving. The flipped classroom supplies continuous learning activities from teachers to students by utilizing the advantages of diverse information technologies. As Abeysekera and Dawson (2015) indicate "[in flipped classrooms] the information-transmission component of a traditional lecture is moved out of class time and replaced by a range of interactive activities designed to entice active learning" (p. 2). By saving lecturing time with pre-recorded video lectures using flipped classroom approach, teachers can design learning-by-doing activities for students to learn in a more authentic mode inside classrooms or a more situated mode outside classrooms.

This chapter aims to contribute the concept, design, and implementation of the flipped classroom for pre-service and in-service teachers to run a flipped classroom. We first discuss the concept of flipped classroom along with two essential components. We then propose the ways for designing flipped classrooms together with six types of classrooms and provide three real examples based on our experiences. Next, we suggest the four-stage methods on how to implement flipped classrooms. In the end, we conclude with the issues and challenges faced in applying the flipped classroom and propose possible solutions.

## 2 The Concept and Design of the Flipped Classroom

The teaching paradigm has shifted from teacher-centered to student-centered recently. As Chen and Chen (2014) indicate, "… a paradigm shift in the modern classroom from teacher-centered, in-class lecture in a physical classroom, to student-centered, blended learning in a flipped classroom" (p. 627). Many teachers are attempting to shift their teaching paradigm to enhance teaching quality. Currently, the flipped classroom is one of the popular methods as it "flips traditional in-class lecture with collaborative active [that] has gained many followers and coverts in K-12 education" (Chen et al. 2014). The general perception of the flipped classroom is to flip the physical classroom as follows.

(1) Lecture versus learning activities (e.g., homework): Teachers conduct the lecturing in the traditional classroom and ask students to complete their homework at home. With the flipped classroom, teachers may ask students to watch video lectures before going to class. Instead of the teachers lecturing in the classroom, teachers may consider having learning activities (e.g., homework) in the classroom.
(2) One-way presentation versus two-way communication: Teachers have lectured by themselves for the whole course in the traditional classroom; now they may ask more questions and provide students more opportunities to communicate.
(3) Few interactions during the classroom versus interactions throughout the whole classroom: Since teachers are required to lecture in the traditional classroom, classes were less conversational and interactive to students. In the flipped classroom, teachers can provide multiple learning activities to communicate and interact with students.
(4) Inside classroom activities versus outside classroom activities: Teachers only provide learning activities in traditional classrooms. However, with flipped classroom teachers also can provide/facilitate learning activities for students after school in order to vary students' learning.
(5) Formal learning versus informal learning: Formal learning only occurs in a systematic intentional way which is delivered by teachers in conventional courses. However, informal learning happens in natural activities without any limitations and forces. The flipped classroom attempts to incorporate informal learning into the teaching paradigm.

Based on these general perceptions of the flipped classroom, we propose three main perspectives for teachers to conduct a flipped classroom. These are concepts of the two essential components, design of the six types of classrooms along with three real examples, and the four implementation stages.

## 3 Two Essential Components of the Flipped Classroom

We propose two essential components that should be considered before running flipped classrooms. The two essential components are: "pre-recorded interactive video lectures" and "highly interactive learning activities."

The first essential component is "pre-recorded interactive video lectures" that is to record a unit/course's lecture onto a video format with interactive activities. There are several ways that pre-recorded video lectures are used currently:

(1) Recording video lectures during physical classroom. For example, MIT open courseware whereby lecturers of the university have live recordings of the classroom lectures and share these videos in MOOCs after editing. Another example is TED Talk videos are taken on site during the conference by a professional production team with several cameras from different angles.
(2) Recording studios in universities and institutions to record high-quality video lectures. These studios are equipped with professional lightings and sound systems and top notch video cameras for the recordings.
(3) Desktop recording tools. It is a more widely accepted method for educators to record their lecture videos by themselves from their desktop recording tools. These lecture videos are more personalize from the learners' prospective; it is as though the educator is having a one-to-one session with the learners.

After the recording of the lecture videos, the conventional way for showing video is in one shot. Nevertheless, we suggest inserting interaction into pre-recorded video lecture. That is to make these pre-recorded video lectures interactive so that students are asked to do certain tasks while watching a pre-recorded video lecture. One important method for making such video lecture is to edit and segment the video lectures. In order to increase learners' engagement and pay more attention on the video lecture if there are interactions in these videos lecture. One of tool that could be useful for video editing is ED Puzzle (http://edpuzzle.com) whereby educators are allowed to embed short quizzes in the lecture videos to engage learners and track their understanding of the materials. As for segmenting the video, Guo et al. (2014) found that videos are more engaging by segmenting these videos into sections shorter than 6 min. Thus, pre-recorded interactive video lectures is first essential component in the flipped classroom.

Another essential component for the flipped classroom is to provide highly interactive learning activities. Learning activities, like collaborations, group discussions, feedback, and reflections, are more likely to engage students compared to one-way lecturing. The design of interactive learning activities can be problem-solving, collaborative learning, peer coaching, situated learning, and/or authentic learning. In other word, teachers utilize pre-recorded interactive video lectures for students before classroom and provide meaningful learning activities instead of lecturing to better assist students in learning a unit/course. Through highly interactive learning activities, teachers offer students a learning-by-doing opportunity to apply what they have learned and to solve the problems they may encounter when watching pre-recorded video lectures. It may also enhance students' learning motivate. Thus, the second essential component of designing highly interactive learning activities is very important for a teacher when she/he is going to adopt flipped classroom approach.

To effectively incorporate the two essential components in the flipped classroom, having pre-recorded interactive video lectures and highly interactive learning activities are keys to the flipped classroom. However, in this era of information overload, there are thousands of video lectures online. We believe that most digital materials (e.g., video lecture) can be easy to be reused immediately as pre-recorded video lectures. Thus, we think that not all of teachers have to invest their time in making pre-recorded video lectures by themselves. Only teachers who can lecture very well should do pre-recorded video lectures. We also advocate that all teachers should be able to provide highly interactive learning content and activities for a course since the learning context will be changed according to different learners, venues, and time. Instead of lecturing in a classroom, teachers have to assist students in learning through videos lecture, not merely showing the whole video to students, but augmenting the video with highly interactive learning activities (e.g., using common shared working space (i.e., text board) and/or collaborative learning).

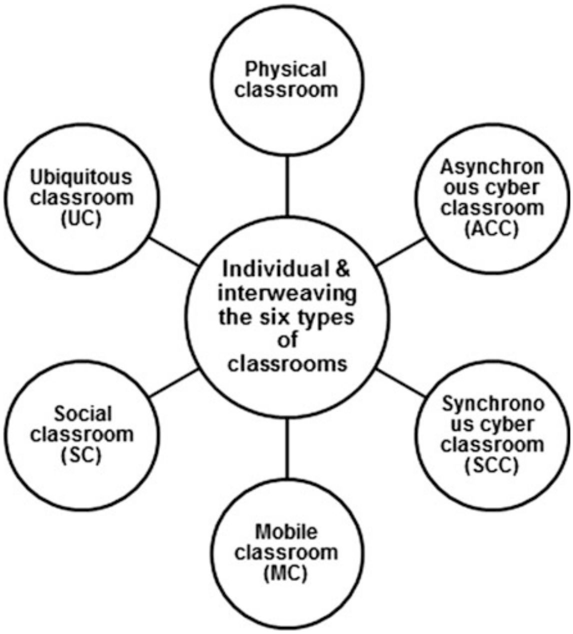
## 4 The Six Types of Classrooms: Supporting Highly Interactive Learning Activities

In traditional classrooms, teachers are only able to provide one environment (i.e., physical classroom) to students, which means teachers only have one opportunity and environment to teach/support students learning a course. In order to help teachers to create a better flipped classroom, we propose the six types of classrooms (as Fig. 1) for teachers to offer six teaching and learning environments for their students. Classroom, course, and environment will be used interchangeably in this chapter to represent learning venue.

The following explains the six types of classrooms.

(1) Physical classroom: This is the most popular teaching and learning format to ask students to participate in a classroom environment. It is a teacher-centered learning methodology in which students have to join a course at a particular place and time. Ideally the benefit for the traditional physical classroom is that teachers and students can directly talk, communicate, and interact with each

**Fig. 1** The six types of classrooms




other. However, students may not able to learn a subject when they are absent and students cannot experience the lesson more than one time or after class.

(2) Asynchronous cyber classroom (ACC): This is a cyber class which provides space and time flexibility for students to learn by means of online resources through networks. It is a student-centered learning methodology, and students can control their own learning time and space. In other words, students can participate in a class anytime anywhere. The benefit for asynchronous class is that students can construct their own learning way. However, students cannot get immediate responses when they have questions.

(3) Synchronous cyber classroom (SCC): This is a cyber class like the asynchronous classroom. However, teachers and students each have control. In other words, teachers only have power to control students' learning time, whereas students can control the place where they join that classroom. Additionally, previous studies (Chen et al. 2005; Hastie et al. 2010; and Wang et al. 2010) indicate that synchronous learning can encourage students to participate in learning activities, because of two advantages—"immediate feedback" and "increased level of motivation and an obligation to be present and participate" (Chen et al. 2005).

(4) Mobile classroom (MC): This is a seamless learning to have additional portable classroom space to provide a quick response and interactions with students (e.g., Line or WeChat).

(5) Social classroom (SC): This is an active social learning which uses social learning (e.g., Facebook) to assist students to learn a subject in an online social networking environment.
(6) Ubiquitous classroom (UC): This is a situated learning which uses pervasive wireless network (e.g., smart watch, QR codes, RFID, NFC, and iBeacon) to provide smart learning environment to students. It is an ideally thought like "internet of things" by providing a smart learning environment to build smart city to extend learning environments for students to go deep into learning a subject.

With the different types of classrooms, teachers have more possibility to provide highly interactive learning activities according to their teaching objectives. Except the physical classroom, the benefits for using other classrooms are the classrooms are online which provide equal distance among all participants. In other words, teachers and students can communicate with the same distance to each other through the internet. However, these six different types of classrooms have their own limitation. Fortunately, teacher can utilize these different types of classrooms for conducting a course that can definitely complement these limitations of the classrooms and provide multiple opportunities for students to learn the material.

## 5 Three Real Examples: Demonstrating How to Use the Six Types of Classrooms

This section demonstrated three real examples to show teachers how to use these six types of classrooms with the two essential components. The key of this section is to demonstrate how to conduct a flipped classroom in three ways—(1) asynchronously providing a series of learning activities corresponding to appropriate classrooms; (2) simultaneously interweaving different types of classrooms with multiple learning activities to learn a related concept/topic; (3) reusing open educational resources (OER) to create meaningful learning activities.

### *5.1 Demonstration 1: Asynchronously Providing a Series of Learning Activities Corresponding to Appropriate Classrooms*

Traditionally, learning activities only occur inside a physical classroom, and these learning activities end when that class is done. Different from the traditional classroom, learning is a continuous process in the flipped classroom that seeks for more effort from teachers and students. In other words, it requires students to work on the learning content in advance (e.g., previewing pre-recorded video lectures) before actually attending the class. At the same time, it requires teachers to provide multiple learning activities for students to learn a related concept/topic. That is, teachers have to design a series of learning activities corresponding to the most appropriate classroom for students asynchronously to learn a related concept/topic. Hence, teachers have to entirely understand the features of each learning activity in order to choose the most appropriate classroom for conducting the learning activity from the six types of classrooms.

Compared to conventional classroom, teachers have an opportunity to use six different types of classroom time by time to provide diverse learning activities for students gradually (from easy to hard, little by little, or time by time) understanding a concept/topic in the flipped classroom. A real example of implementing the flipped classroom into a course is "Innovations and Pedagogies in e-Learning" which was conducted by a university professor who had over 15 years of experience in e-learning file study in a Taiwanese university. The professor first utilized "asynchronous cyber classroom" to conduct his flipped classroom by asking the students to watch pre-recorded video lecture. Then his students have to share their discussions by posting on the forum and having peer discussions on the forum before going to cyber face-to-face classroom. If necessary, that professor would use mobile classroom to encourage the students to active participate in asynchronous space learning activities. Finally, the professor conducted synchronous cyber classroom by asking his students to participate in a cyber face-to-face classroom. His students can orally share their ideas on "Innovations and Pedagogies in e-Learning" in the cyber face-to-face synchronous cyber classroom, and/or that professor can discuss issues that students may encounter during asynchronous cyber learning. Hence, the professor had conducted several types of classrooms asynchronously to help his students to learn the topic of "Innovations and Pedagogies in e-Learning."

### 5.2 Demonstration 2: Simultaneously Interweaving Different Types of Classrooms with Multiple Learning Activities to Learn a Related Concept/Topic

Compared to conventional classroom, teachers could simultaneously interweave different types of learning classrooms with multiple learning activities to facilitate students to learn a related concept in the flipped classroom. Teachers not only would lecture in (cyber) face-to-face classroom, but also can combine other types of classroom (e.g., utilizing mobile classroom or social classroom) to conduct other learning activities simultaneously. There are two ways for teachers to conduct a flipped course: "Physical classrooms plus others types of classrooms" and "Synchronous cyber classroom plus others types of classrooms." "Physical classrooms plus others types of classrooms" is used for K-12 teachers to conduct a flipped classroom by asking students to watch pre-recorded video lecture (online classroom) before actually having activities in a physical classroom (offline classroom). "Synchronous cyber classroom plus others types of classrooms" is that a cyber face-to-face classroom is substituted for physical face-to-face classroom. This mode is more suitable for mature learners like college students or working adults to participate a flipping course in which teachers fully utilize a cyber face-to-face classroom, instead of physical classroom, to combine other types of classrooms so as to give students the maximum flexibility.

The similarity between two ways of conducting the flipped classroom is to use other types of classrooms to facilitate students learning a concept/topic (e.g., asynchronous cyber classroom for learning interactive pre-recorded video lectures or mobile classroom for seamless learning). The difference between these two ways is learning venue by shifting the physical classroom from the physical face-to-face to cyber face-to-face classroom.

With the flipped classroom, it is indispensable that teachers should have the capability to interweave more than one type of classroom into a course to learn a related concept/topic simultaneously because it can make that course more powerful and students can fully participate in that course. A real example is about self-introduction. A teacher conducted a cyber face-to-face classroom in synchronous cyber classroom by asking students to make oral presentation to introduce them. At the same time, that teacher also asks these students to introduce themselves by posting resume or biography on online forum (asynchronous cyber classroom). Simultaneously, that teacher can ask student to report currently location, or to ask students to go to a social classroom by using Facebook to share their Facebook information/activities. Hence, teacher can understand individual students' background more as well as their peers. Students also can know more classmates by reviewing their self-introduction from synchronous cyber classroom, asynchronous cyber classroom, mobile classroom, and social classroom.

## *5.3 Demonstration 3: Reusing Open Educational Resources (OER) to Create Meaningful Learning Activities*

Different from the aforementioned perspective to pre-recording your own video lectures in advance, we further suggest teachers to reuse open educational resources (OER) as pre-recorded video lectures and to focus on creating meaningful interactive learning activities by integrating with six types of classrooms. That is, teachers should put their efforts in designing highly interactive learning activities which is another essential component we propose for teachers when they run the flipped classroom. Highly interactive learning activities are to create learning materials consisting meaningful activities in learning venue (either asynchronously or simultaneously using the six types of classrooms). In other words, since OER videos are readily available and used to make more interesting and educational video to learners, teachers should consider utilizing OER videos such as the videos on YouTube or TED Talk as pre-recorded video lectures. Hence, teachers can use these OER videos as references to provide more practical examples to further elaborate the material of the course in a flipped classroom. Or teachers can depend on the learning goal to divide and transform these OER video into segments and interactive videos to conduct several types of classrooms to facilitate students learning a topic/concept. This is different from conventional way of teachers making their own lecture and present a concept/topic once in the physical classroom. At the same time, appropriately reusing OER may also solve cost issues for teachers or low education budgets.

A real example is that the professor taught a topic “e-Learning Concept” in the Innovations and Pedagogies. The professor provided a pre-recorded video lecture by using video from TED Talk and asked his students to learn the topic of “e-Learning Concept” from TED Talk. This helped students to get more ideas about this topic as a Self-directed learning in the asynchronous cyber classroom. Then, the professor requested students to post three questions that students had after listening that video from TED Talk. Finally, the professor conducted a cyber face-to-face discussion by using synchronous cyber classroom to further discuss the concept of e-learning based on the posts which students already shared in the discussion forum. Also, he asked students to cooperate with each other by using collaborative learning and peer coaching. In the end, students should be able to integrate “e-Learning Concept” into different fields.

## 6 The Four Implementation Stages of the Flipped Classroom

The flipped classroom currently becomes predominant in teaching and learning. It attempts to help teachers to create diverse teaching–learning contents and activities for a unit/course as a blended learning. Different from blended learning, the flipped classroom also attempts to provide more learning opportunities for student to learn anytime and anywhere in order to satisfy different learning styles of students and their different needs. Thus, how to actually implement the flipped classroom’s concept and design real courses should be considered in a flipped classroom presentation.

We propose a four-stage method for teachers to conduct a better flipped classroom that includes designing learning content, leading learning activity, guiding students with specific learning difficulties, and managing a good learning atmosphere across multiple learning environments/classrooms. Each stage should fully utilize the aforementioned two essential components and six types of classrooms.

- First stage is designing learning content. In this stage, a teacher has to prepare the learning materials before actually conducting a course. Instead of only giving lectures in the course, a teacher needs to design learning content (e.g., video lecture, homework, and group term project) which appropriately matches a unit/course objective before actually having that unit/course. Thus, effectively utilizing two essential components (pre-recording interactive video lecture and highly interactive learning activity) is very important when designing learning content before actually having a course. Additionally, different learners' styles can influence their learning performance in different environments. Teachers also need to consider students learning style by integrating pre-recorded video lectures (content) with the six types of classrooms to design interactive learning content and learning activities for students.

- Second stage is leading learning activities. It happens during a course where a teacher has to lead the learning activities in class based on learning content that she/he designed before having a course. Since students may have their own learning pace, as a teacher, she/he should be able to lead students to attend any kind of interactive learning activities which integrates/interweaves with the six different types of classrooms in order to facilitate students to entirely understand a concept and to achieve the curriculum goals. Hence, the goal of the second stage focuses on how teachers have to lead student to learn. For example, a teacher assigns students to listen to TED Talk and asked students to share their comments/ideas on asynchronous cyber classroom. The teacher can lead students by making acknowledge of the active students in synchronous cyber classroom or encouraging students from mobile classroom to complete this learning activity.
- Third stage is guiding students with specific learning difficulties. Different students have their own different learning difficulties during course time. During a course, teachers should be able to guide a specific student when she/he has difficulty learning a concept/topic during/after the engagement of learning that concept/topic. In other words, a teacher should realize his/her students' specific questions and guide them to solve these questions in the nick of time. Hence, teachers and computer systems should interplay which means teachers can use computer learning systems to record all the students' learning activities as log files which can be analyzed by teachers or software agent to identity students' learning difficulties. Once a student's learning misconception or difficulty is being identified, the teacher can then help an individual student to solve his/her specific learning problems. Additionally, these learning logs are big data on which teachers can depend to conduct learning analytics and/or to create learning software agents to automatically help students to solve learning problems. These learning logs and teaching support software agents can help teachers to guide students with specific learning difficulties and reduce teachers' effort of workload.
- Last stage is managing good learning atmosphere across multiple environments: It happens all the time during a course where good learning atmosphere management should occur anytime when a teacher conducts a class. A teacher should be able to manage his/her own classroom atmosphere in different types of classroom for a flipping course. For example, a teacher can acknowledge students who are more active in joining the class activities or have a good learning performance. Furthermore, a teacher can show students his/her passion

for delivering better learning content and activities to them by decorating the teaching environment which fit to learning context. A teacher can build his/her classroom culture to lead and encourage students' deep learning. Thus, a teacher can fully utilize two essential competences, six types of classrooms, or even integrate diverse technology to assist teaching and learning which are important for managing a good learning atmosphere. It may also influence his/her students learning performance.

## 7 Issues, Challenge, and Possible Solution for the Flipped Classroom

Generally, to teach effectively, teachers should have their own subject domain knowledge as content knowledge (CK) to enable teaching with the knowledge of teaching and learning methods, processes, and strategies (i.e., pedagogical knowledge, PK) to aim for their instruction. To successfully integrate technology into their instruction, teachers are required to have knowledge of how to use technology (technological knowledge, TK) in order to encompass appropriate technologies such as computers, information and communication technology (ICT), and/or digital video. Thus, it is important to ensure that teachers possess technological pedagogical content knowledge (TPACK) in order to know how to incorporate applicable technology with teaching strategies when teaching specific subject matters (Koehler and Mishra 2005).

The following section presents the framework of technological pedagogical content knowledge (TPACK) to discuss issues and challenges we faced when implementing the flipped classroom. Also, we proposed feasible solutions to address these issues and challenges in order to facilitate teachers to implement the flipped classroom in their courses.

Teachers' Technological Literacy and Capability.

There are three areas of knowledge—content, pedagogy, and technology, when teachers integrate the usage of technology into their courses. In the flipped classroom, teachers are able to utilize pre-recorded video lectures to present their content knowledge to students, incorporate more teaching strategies and learning methods (pedagogical knowledge) to provide highly interactive learning activities instead of lecturing, and integrate applicable technologies into six types of classrooms in order to enhance students learning performance. Hence, expecting teachers' specializations, teachers' awareness of the flipped classroom as a teaching paradigm is the most important concept. As Davies (2011) stated, educators should have the framework of the three levels of technological literacy—awareness, praxis (i.e., training), and phronesis (i.e., practical competence and practical wisdom) for incorporating technology into their teaching.

Additionally, the flipped classroom may create difficulty for teachers in designing course scope, content, and learning activity when they performing the flipped classroom. Hence, if teachers are not able to perform a meaningful flipped classroom, it is imperative for teachers to participate in the flipped classroom's professional development training or have enough technical support for teachers to integrate technologies into their different types of flipped classrooms. Therefore, the main challenge we faced when conducting the flipped classroom is methods to build teachers' technological literacy and capability of using the flipped classroom.

The Value of Formal Learning will be Diminished.

Considering teachers' knowledge of content and pedagogy together as pedagogical content knowledge (PCK) can facilitate teachers to applicable teaching a specific content as said by Shulman (1986). However, students nowadays spend 50% of their learning day doing formal learning and 50% of their learning day doing informal learning. What do you expect a student's time allocation between formal and informal learning will be in 20 years from now? As a teacher, how to compete with informal learning becomes an important issue that challenge teachers' pedagogical content knowledge (PCK). We proposed a solution is to embrace informal learning to integrate into formal learning activities since more and more students would spend their time on an informal learning environment. Hence, teachers enable to unitize informal learning environment for formal learning activities to supply students with a variety of learning activities. Therefore, to solve second challenge of the value of formal learning diminished is to "Embrace Informal Learning by Having the Flipped Classroom."

The Initial Knowledge Level of Each Student will be Enlarged.

Performing the flipped classroom, it requires teachers' technological content knowledge (TCK) to interweave learning content with diverse technologies in order to provide more different types of classrooms. At the same time, it required teachers to have teaching strategies and technological capabilities as technological pedagogical knowledge (TPK) to combine more effective learning pedagogies (e.g., constructivism or learning pyramid) and learning activities (e.g., authentic learning or situation learning) with applicable modern technologies in order to supply different types of classrooms. Nevertheless, students can easily learn anytime and anywhere online (informal learning) in this era of information overload, which enlarges each student's initial knowledge level. Also, different students have different learning styles, and each student's initial knowledge level may be different. As a teacher, how to supplement students' different initial knowledge levels is an issue/challenge in the future. Teaching becomes even harder for teachers.

We proposed "Teachers in the Clouds and Team-Teaching." That is, if we incorporate other teachers/educators to implement team-teaching to provide students the flexibility to select different pre-recorded video lectures on the same topic/subject or to provide more learning activities by using different teachers. These pre-recorded video lectures and learning activities could come from other teachers and/or former students' project to show students the same topic of different version and venues. It would assist students to learn from different teachers which would satisfy different students' requirement as each student has different initial knowledge and learning styles. This would enable sharing of academic resources among lecturers in making learning more efficient and diversified. For example, a teacher wants to teach students "how to build an mBot robot." She/he can apply authentic learning into his/her classroom. She/he first prepares different videos to introduce about "what robot are" and "what is an mBot robot." All his/her students are required to watch the pre-recorded videos before go to the classroom. In the classroom, students are learning-by-doing to build a real mBot robot instead of listening to teacher lecturing. Thus, that teacher provides a seamless learning approach for student to learn and build a robot. As Lombardi (2007) indicated that "learning-by-doing is the most effective way to learn" (p2). Another example, a teacher wants to teach student about "plant." She/he either can create his/her pre-recorded video content about plant or can reuse the content from the Clouds by other teachers. Then, students can have a field trip to botanical garden to observe what they have learned from pre-recorded videos. Therefore, students can connect the knowledge they learned from videos to plants in real life.

Ownership Shifted.

The last challenge we faced is how to actually shift teachers' teaching ownership to students' learning ownership. Considering all of the knowledge elements together to get technological pedagogical content knowledge (TPACK) is indispensable for teachers to perform a flipped classroom. As Davies (2011) indicated, "the challenge for educators is to understand how best to teach with technology" and "appropriate and effective use of technology is context dependent and contingent on the specific learning situation" (Davies 2011, p. 49). It is limited teachers to teach a course in conventional classroom since teachers only have the ownership to control time, place, teaching content, and learning activities when they teach a subject matter. Teachers' teaching ownership also makes most students having passive learning behaviors. Thus, we proposed the ownership to be shifted. That is to build students possessing learning ownership and active learning behaviors in order to maximize TPACK value.

With the flipped classroom, it provides more flexibility ownership for teachers and students. Teachers offer students opportunities to learn by themselves. For example, teachers are required to provide pre-recorded video lecture to students before actually having a (cyber) face-to-face classroom. At the same time, teachers have more time to prepare and lead different learning activities by using different types of classrooms to help students to learn a concept/idea/unit. Also, teachers can transform their lecturing time to guide students to solve specific learning difficulties. In this situation, students would be able to develop their ownership to decide when and where to learn the necessary content. That is the way that the flipped classroom facilitates teachers to shift their teaching ownership to students to develop students' learning ownership and active learning behaviors. Thus, the flipped classroom required teachers possessing TPACK in order to complete teachers' ownership transference and cultivate students in having their ownership and becoming active learners. It may also assist with educational progress.

## 8 Conclusion

*The World Is Flat: A Brief History of the Twenty-First Century,* by Thomas Loren Friedman, shows that because of diverse technologies, people have equal opportunity to access the internet, create their own content, connect with one another, share sources, search/retrieve information, and even collaborate online. With globalization, our world becomes flatter. Similarly, while global access to information is changing, there is no reason that education cannot change at the same speed and/or intensity. Education is in the service sector. The product of education is quality teaching and learning, and our customers are learners/students. In order to enhance students' learning processes and performance, this chapter proposed to incorporate the flipped classroom with six types of classrooms for providing more learning flexibilities and decentralizing teachers' control to students. In particular, the ubiquitous classroom is more suitable for implementing authentic learning or situated learning activities. It is hoped that pre-service teachers and in-service teachers will benefit from this chapter and reflect how to design an effective classroom.

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# Making Without Makerspace, Another Study of Authentic Learning with Augmented Reality Technology

**Chung-Ming Own**

**Abstract** A "makerspace" is an area in a library where users can use tools and equipment to design, build and create all sorts of different things. It may be a dedicated room or a multipurpose space in which a collection of raw materials and resources can be utilized as desired. However, the makerspace is not always in everyplace and for everyone to use. In this study, we explore a new way to integrate advanced display technology into educational activities for students with different disabilities. An interactive augmented reality application was developed to facilitate the learning of robot building. The result shows that AR system could help the school students to finish their robot building independent of teacher's assistant. With the use of AR display technology, the participants demonstrated improve ability to complete construction tasks when compared to the use of traditional paper-based methods. Performance data indicated that the use of AR technology could enhance learning motivation and frustration tolerance in students and the authentic learning principle is further identified.

**Keywords** Authentic learning · Makerspace · Augmented reality

## 1 Introduction

Recently, the learning theory provides the ideas and thought to implement the student-centered, realistic and effective learning environments. However, it is not sufficient to supply suitable examples from real-world situations to illustrate the concept being thought in our daily life. It needs to create a physical environment with the knowledge we can use, and supplies the resources to exam from distinct perspectives (Honebein 1993). That is what we called the makerspaces.

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### 1.1 Constructionism and Representation

Makerspaces are comprised of participants with different ages and levels of experience; these spaces all are based on the making and developing ideas and constructing them into the reality. The centrality of developing an idea and creating an external representation of that idea is the core doctrine of constructionism (Harel and Papert 1990; Kafai 1995). Constructionism builds on the perspective of the psychological sciences, which holds knowledge as the activities constructed by learners via their experiences treats learning as the revision of mental representations. This thought extends the theory of constructivism to focus on the making of external artifacts, which can support them on the conceptual understanding. From the constructionist point, the functions of artifact are combined with the learner's thinking; hence, the learner could interpret the artifact as their representing object and this process is referred as the improving knowledge.

### 1.2 Learning Environments for Making

To understand makerspaces as learning environments, we draw from the literature on both formal education environments for making and informal communities of practice the diverse learning and teaching arrangements present in these spaces. Many makerspaces resemble studio arts learning environments, where participants work independently or collaboratively with materials to make (Halverson and Sheridan 2014b). Based on analysis of intensive visual arts classes, Hetland et al. (2013) identified four key "studio structures" as central to the design of studio learning environments: (1) in demonstration lectures, teachers pose open-ended challenges, show exemplars and demonstrate processes to engage and inform students, (2) in students-at-work, students work on their art and teachers circle the room observing and giving "just-in-time" instruction, (3) in critiques, the working process is paused as the group collectively reacts on student work and (4) in exhibitions, students' work is shared with a community beyond the studio classroom. Figure 1 is the makerspace in the Tianjin International School, Tianjin, China.

## 2 Making Without Makerspace

However, do we really need the well-functioned makerspace? Can you remember the first time you see a 3D printer in your working laboratory? It is unlike the slim LED TV or a washing machine, the magic idea can be made in my own place. That's why our first thought was: we need to buy one of those as possible as we

**Fig. 1** The makerspace in Tianjin International School

can. However, we had a second thought about it, do we really need it or do we know how to operate this machine?

Instead of buying a fairly expensive machine in the makerspace, we got hold of someone who actually knew about the newly machine. The local makerspace had lots of experts, and they were happy to share their knowledge. Hence, we can conclude the three main practices we defined from the makerspace: they are sharing, creating and participating. Generally, in the makerspace, we all focus on the sharing, but perhaps we are lacking the last two. Besides, the budget of maintaining makerspace is limited, makers have not so many chances to practice their idea for real, and let alone the remote places have no money to maintain the makerspace.

## 2.1 New Technology of Augmented Reality

Based on the real-world and abstract objects, usage 3D data set to describe an environment is the virtual environment; the term VE can refer to a technology of Virtual Reality (VR), which uses the computer graphics systems in combination with various display devices to provide the effect of immersion in the vivid 3D computer-generated environment. Besides, technology of augmented reality (AR) creates the sensation of virtual objects which present in the real world. Combining the technologies of AR and VR is the mixed reality (MR), which not only provides rich learning patterns and teaching contents, but also helps to improve learner's ability to analyze problems and exploring new concepts; Fig. 2 shows all of these productions. Users can explore and experience in the virtual environment is unlimited; MR technology in education also can be viewed as the next generation of blended learning sued as the realistic and authentic environment. MR can be referred as the system which combined real and virtual, interaction in real time and surrounding environment. Brett explained that AR interface combines aspects of virtual reality and the real-world environment by providing a person a chance to view one or more virtual 3D objects in real space (Brett 2003). Milgram defined the virtually continuum spans from the real environment to a pure virtual environment (Milgram and Kishino 1994).

Recently, some governments have implemented initiatives with the aim at improving the quality and effectiveness of the teaching and learning process. For example, Malaysia has their poor teaching problems; they follow the chalk and talk teaching method and use the static textbooks but fail to engage students. In 2007, Teoh and Neo reported that it was boring to just hear the lecturer talking in front of them (Teoh and Neo 2007). The researchers conclude that the integration of technologies could help them in the improvement of learning process. One of the students suggested that an expert should be present in the classroom to provide them with the relevant context for the subject and make the classroom activities more interesting (Bevins et al. 2005). Students prefer to learn in interactive ways than the traditional teaching methods; besides, they commonly find science subjects requiring a depth of understanding and skills. When students have difficulties in understanding the concept well, it can interfere with the students' learning of scientific principles and concepts.


**Fig. 2** **a** VR demonstration (Oulus), **b** AR production (MASVIS), **c** MR production (Microsoft)

Thus, to avoid and minimize the students' misconception, visualization technologies have exciting potential for facilitating understanding and preventing misconceptions in the scientific domain. Kozhevnikov and Thornton (2006) found that it is possible to improve students' visualization skills by presenting a variety of abstract visual images and allowing the students to manipulate and explore the images. There is a wide range of available technologies that can be used for the visualization of abstract concepts. Robertson et al. (2008) found that animation together with fascinating data and an engaging presenter helps the audience understand the results of an analysis of information. These visualization technologies can be used to address the problem of misconception and help students understand better.

In 2011, Martin et al. proposed that AR is a new technology that is likely to have an impact on education (Martin 2011). AR is distinct from VR, because AR combines the real world with computer graphics, while VR immerses the user in a computer-generated world. AR is a new way to improve the learning of the virtual information help. According to Cerqueira and Kirner (2012), there are several advantages of using AR techniques for educational purposes. For example, AR can minimize the misconceptions that happen with the inability of students such as chemical bonds. AR can allow detailed visualization and object animation. The other advantage is the macro- or micro-visualization of objects, because some of them are too difficult to be seen via the naked eye. With the AR help, students can understand the subject by displaying their information at different viewing angles.

Besides, many researches show that students are excited to learn with the AR technology. For example, Klopfer and Squire proposed that students gave positive feedback about their experience on the combining of virtual and real environment (Klopfer, 2008). Burton reports a similar result with the participants in the study of potential of AR technology of sharing information and learning on new concepts (Burton et al. 2011). In addition, AR makes students become more active in the learning process by the interactivity of the applications (Lamounier et al. 2010). It would encourage students to work creatively by improving their experiences and understanding. The advantages of AR indicate that there is significant potential to integrate virtual information and real environment in teaching and learning, especially for the subjects that require to visualize.

## 2.2 The Limit of AR

A number of limitations exist in the AR technology. For example, according to Hsu and Huang (2011), various participants in an AR learning exercise agreed that the AR tools are good but most participants did not consider the tools to be as effective as reading textbooks. They also argue that using AR tools was not easy to obtain learning information. Although AR tool is easy to operate, the procedure of sending the image, recognizing the text and understanding the meaning of the text is troublesome and time-consuming. Besides, the user may need to wait for the location decoding and information to be transmitted back from the server.

Another experience is reported by Folkestad and O'Shea (2011); they discussed when they tried to use AR technology outdoors and had to resort to asking their teacher for help, because of the using frustration. The results indicated that although the students encountered technical problems, they have to find assistance, persist with the task and engage effectively in the unique learning process. Despite all the difficulties, the involvement of AR technology was still popular in the outdoor (Folkestad and O'Shea 2011). Moreover, research should be conducted to investigate the latest technology called the mobile augmented reality (MAR) system which is a smartphone application that is integrated with the AR itself. This new form of AR technology offers a learning experience that is linked to the formal classroom so that students can learn outside of class hours and outside of school limits (Burton et al. 2011).

The limitations stated above mostly highlight the issues related to the technical aspects of using AR in the learning process. Such technical issues must be improved in the future in order for AR to be widely applied in education. Lamounier et al. (2010) also pointed out that there need to be improvements in Internet portability in order to facilitate user access to AR systems for learning. Increased Internet access will give students the opportunity to use AR via a smartphone. This has the potential to make AR a powerful learning tool that can help students to gain content knowledge and maintain that knowledge through their interactions with the smartphone activities.

## 3 The AR Application

Some of the significances of the AR applications are listed as follows:

- Draws people's attention: As a new technology, AR draws people's attention. Drawing students' attention is an important factor in teaching.
- Constructivist learning environment: AR technology can be utilized to create a constructivist environment to enhance learning. In 2006, Chen used AR as an alternative way to view the chemistry world and allowing students to engage with the system and discover knowledge on their own (Chen 2006). Sensorimotor feedback: AR can increase reliance on sensory information, allowing users to interact with the system by using their body, especially hands which provide "sensorimotor feedback." Users also can obtain a sense of spatial feeling.
- Authentic Learning: The question of authenticity hinges on the context in which the task can be perceived as authentic. The core idea of authentic learning is to provide real materials and real activities. MR ability to annotate real elements and the ability to add to reality by superimposing virtual aids will aid in instruction and learning for those disciplines where a specific spatial configuration of elements must be learned and remembered.
- Realistic models: AR provides a means of "seeing" phenomena in 3D, thereby bringing the contextual three-dimensional nature of the real world to their learning. Textual and pictorial information in the typical two-dimensional print-based resources loses much of the richness of the "real" world elements and involves an element of interpretation that is rather difficult for some students.

Thus, according to our previous discussion, some of the AR systems applied in the authentic learning are listed as follows.

### *3.1 Book of Augmented Reality*

Nowadays, we have many presentation ways of the learning books. For example, an electronic book can be an electronic version of a traditional text; conversely, a traditional book can have the audio or multimedia CD ROM electronic features. Marshall et al. show that users love the physicality of the real book, because it offers a broad range of advantages, like flexibility, robustness (Marshall 2005). However, traditional textbooks or any form of printed publication suffer two disadvantages:

inability to directly portray three-dimensional object and the inability to convey time-evolving information in a dynamic way (Craig and McGrath 2007). Besides, the combination of physical books with new interaction offered by AR/MR media is the newly trendy. This kind of book is an interactive paper implementing some form of physical-to-digital link where physical artifact particularly paper documents becomes augmented with digital information. Figure 3 shows the example of Disney Research book.

## 3.2 App of Augmented Reality

Most people who interact with AR for the first time have a mind-blowing experience but fail to consider classroom applications. In our elementary school classrooms, we use AR to create active learning experiences, those are inconceivable to prepare the real environment, and in the process we redefine the learning space! Educators know that learning deepens, not just through reading and listening, but also through creating and interacting. With augmented reality system helping, students manipulate and combine elements during the learning, rather than just reading about them in a textbook.

For example of AR app, Aurasma allows users to engage in and create AR experiences of their own. Educators and students can use this open-source tool to essentially bring their learning to life. We have seen Aurasma used several different ways in the classroom; some cases are shown as follows:

- Homework Mini-Lessons: When students scan a page of their homework, the page reveals a video of their teacher helping them solve a problem.

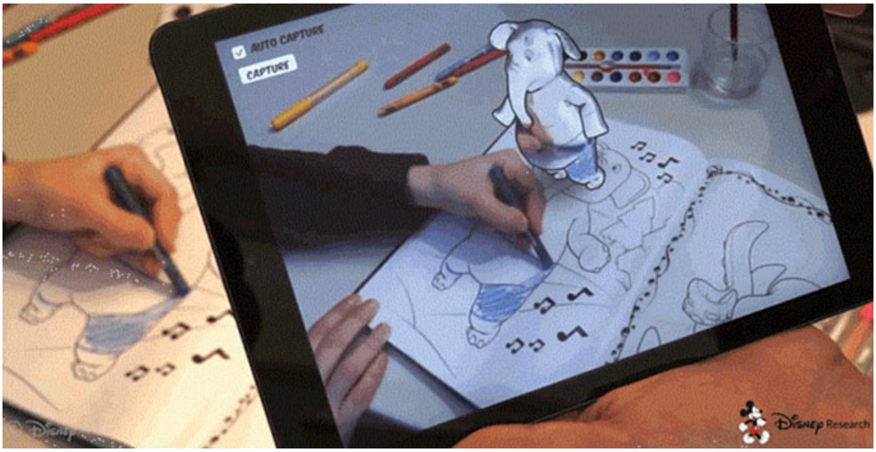


**Fig. 3** The example of Disney Research book (Disney Research)

- Faculty Photo Wall: Set up a display of faculty photographs near the school entrance. Visitors can scan the image of any instructor and see that figure comes to life, telling more about him- or herself.
- Book Reviews: Students record themselves giving a brief review of a novel that they just finished and then attach that "aura" (assigned digital information) to a book. Afterward, anyone can scan the cover of the book and instantly access the review.
- Parent Involvement: Record parents giving brief words of encouragement to their child, and attach a trigger image to every child's desk. Anytime students need to hear encouraging words from their parent, they can scan the image on their desk for virtual inspiration.
- Yearbooks: From tributes to video profiles, from sports highlights to skits and concert footage, the ways that AR can enhance a school yearbook are limitless.
- Word Walls: Students can record themselves providing the definitions of different vocabulary words on a word wall. Afterward, anyone can use the Aurasma app to make a peer pop up on screen, telling them the definition and using the word in a sentence.
- Laboratory Safety: Put triggers (images that activate media when scanned by an AR-enabled device) all around a science laboratory so that when students scan them, they can quickly learn the different safety procedures and protocols for the laboratory equipment.
- Deaf and Hard of Hearing (DHH) Sign Language Flashcards: With AR, flashcards of vocabulary words can contain a video overlay that shows how to sign a word or phrase.

Besides, in an astronomy class, students learn about the structure of the universe, and the relationships among earth, moon and sun. Sometimes, it is hard to explain how the universe evolved; for the sake of students understanding, teachers may employ AR technology with 3D-rendered celestial body. For example, in Shelton's (2004) study, he described the virtual sun and earth are manipulated on a small mobile device that changes its orientation in coordination with the viewing perspective of the student. Besides, Johnson et al. designed the AR application to introduce the Google SkyMap; users can browse the sky with the see-through view from the camera on their smart phone (Fig 4).

### *3.3 Car Repair with Augmented Reality*

AR—a digital layer superimposed on top of the real world—is being used for car applications today. Manufacturers are tapping the technology to help service technicians make repairs by putting on special goggles or pointing iPads. Even better, app makers are on the verge of releasing consumer apps that will help you repair your car in your own garage—perhaps allowing you to avoid an expensive trip to the mechanic.

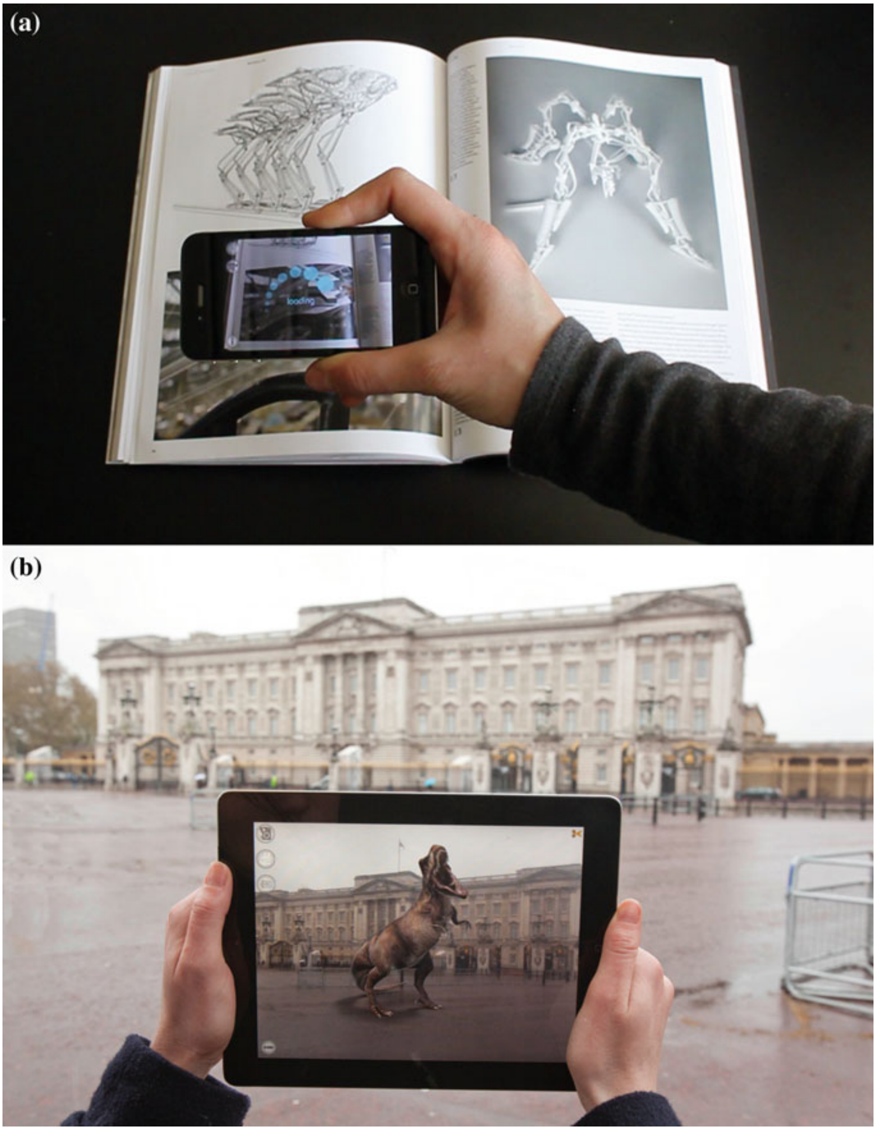


**Fig. 4** The application of Aurasma, **a** the architecture representation, **b** T-Rex at Buckingham Palace

Volkswagen started dabbling with AR in its service training centers in 2010. Its research laboratory created a projector system that acted like a virtual X-ray, showing students components behind the car's exterior. It used video cameras to track students as they moved about the room, so the projector could adjust its image to display the correct perspective to the viewer—no special glasses were needed.


**Fig. 5** ARmedia augmented reality 3D tracker

The AR must have proven an effective training tool because now Volkswagen is moving it out of training centers and into service centers. The German automaker has teamed up with Metaio GmbH to create Mobile Augmented Reality Technical Assistance (MARTA) for the iPad. Service professionals simply point the tablet's camera at a car engine and look at the screen to see virtual components, and step-by-step animations appear in relation to the real components to help them complete their task.

Mechanics only needed to calibrate the app by pointing the camera at the right angle to the car—indicated by a silhouette on screen—and could then begin a repair job. In addition to animations showing what must be done, the app even instructs what tool must be used. Figure 5 is the demonstration of the car repairing AR.

## 4 Conclusion

In this study, the AR approach is proposed for conducting authentic-based learning activities. The learning systems were developed based on advanced interaction with bared eyes. The usages result shows that the AR approach is able to improve people's learning performance in learning activities owing to the use of AR technology in linking the real-world contexts with the digital learning resources at the right place and the right time. Such learning scenarios that present relevant materials (e.g., images, texts, videos) in a well-integrated and organized form can avoid creating incidental cognitive mistakes and improve students' learning performance. On the other hand, in a traditional instructional approach or makerspace's rules, the targets and the corresponding materials are presented separately and asynchronously. When observing the real-world targets, the attenders need to read the corresponding materials from the printed sheet and put lots of efforts on organizing the information by themselves, which prevent them from viewing the learning targets and thinking in a higher-order manner.

Although the AR-based learning system benefited the students in this application, there are some limitations to be noted. First, positioning and recognition accuracy of the AR devices limits the display of the location of the learning objects; therefore, when designing a learning task, the teachers need to consider the size of the learning objects and the distance between them. These ideas can assist the system to locate the object area. Besides, to provide instant hints or learning guidance to individual students, the teachers need to develop learning processes for evaluation purposes and digital learning material to provide learning supports.

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## Author Biography

**Chung-Ming Own** was born in Chiayi, Taiwan, in 1970. He received the B.S.E and M.B.A degrees in Information Management from the Fu Jen Catholic University in 1996 and National Yunlin University of Science and Technology in 1997, respectively. Between 1997 and 2005, he attended the department of Computer Science and Information Engineering at the National Chung Cheng University and completed the PhD degree requirements under the supervision of Prof. Pao-Ta Yu. Between 2006 and 2013, he has been an Associate Professor at St. John's University in Taipei, Taiwan. During that time, he accepted the official position as the College Secretary of Electrical Engineering and Computer Science. Between 2013 and 2014, he was a visiting researcher at the School of Electrical and Computer Engineering of Georgia Institute of Technology in Atlanta, Georgia, USA. Since September 2014, he is a visiting researcher at the College of Computer and Information Engineering of Chuzhou University in Anhui, China. He joined the School of Computer Software of Tianjin University in Tianjin, China, in January 2015 as an Associate Professor. He is conducting research at the Digital Innovation laboratory.

# Part IV
# Next Step for Authentic Learning

# Future Trends of Designing Learning in the Global Context

**J.M. Spector**

**Abstract** It is clear that educational technologies are being introduced at an increasing rate. It is also clear that many of today's students have grown up with digital technologies. What are the implications for the design of effective learning environments and instructional systems give such changes? Many have predicted that radical changes in learning designs are required, although there is insufficient evidence to support the claims of effectiveness of many of the proposed changes. This chapter recognizes changes introduced by new technologies and new learners. However, recalling lessons that have been learned or should have been learned from previous educational technology integration efforts are vital in making sustained, systematic, and systemic improvements in learning and instruction.

**Keywords** Holistic approaches · Instructional design · Learning designs · Technology trends

## 1 Introduction

Some of the key technologies that have impacted learning and instruction in the last 100 years include (a) radio and television, (b) multiple media (e.g., audio, graphics, video, animation), (c) teaching machines, (d) word processing, (e) the Internet, (f) personal computers, and (g) social media. Within each of these arbitrarily chosen seven categories, there are multiple technologies and pedagogical applications that can be cited. Many started as small-scale projects, and most were accompanied by claims that education would be radically transformed as a result of the new technology. While small changes and incremental improvements have occurred, there have been few large-scale, sustained efforts that have had a positive impact on

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learning and instruction as a result of these changes. Given that brief historical synopsis, why should one believe that the many technology innovations now being introduced will result in radical change and improvement?

First consider the notion of sustainment. Which of those technology innovations have been sustained for more than a generation or even more that 10 years? One application of a new technology does stand out from among the many other prominent and promising efforts over the years—namely, Sesame Street, which aired on public television in the USA in 1969 (see https://en.wikipedia.org/wiki/History_of_Sesame_Street). The show featured muppet characters and was aimed primarily at teaching young children (six and under) basic skills such as the alphabet, simple words, basic arithmetic, and more to help ensure their success in elementary school. Grants from the Carnegie Corporation, the Ford Foundation and the federal government helped Sesame Street become a reality in the form of the Children's Television Workshop. Sesame Street is still active after more than 40 years (see http://www.sesamestreet.org/). Research has strongly suggested that Sesame Street has helped prepare young children for school and improved school readiness, especially for boys and minority children (Kearney and Levine 2015). While those gains may be lost by the time the children reach middle school, the program has grown from a grant-funded effort to a national enterprise and managed to thrive for almost two generations.

One should ask what has contributed to that remarkable record of success and the lack of sustained success by so many other outstanding innovative efforts across the decades of educational technology innovation. The answers to those two questions are complex and probably contentious. Sesame Street had significant funding at the outset. The shows were well designed and aimed at specific albeit simple learning goals. The muppet characters were engaging for the target audience. Live shows with children recruited from around the country gave the show a real-life feeling to which many children could relate. Other characteristics could also be cited. What stand out are (a) clear and measureable goals, (b) well-designed and engaging activities, and (c) continuous support and refinement. Other efforts, however innovative, have not enjoyed all three of those characteristics. Most efforts do not have ongoing support, at least not in the USA. When the grant expires, the researchers and technical support staff disappear and the innovation quickly fades into disuse given the everyday demands placed on teachers. Many technology innovations are indeed well-designed and engaging for students. What comes to mind is the Adventures of Jasper Woodbury (Bransford et al. 1990; CTGV 1992). The Jasper project began in 1989 and consisted of a number of videodisks supporting problem-solving activities in math, science and other disciplines; it was grounded in anchored instruction and inquiry-based learning and was well-researched with regard to the impact on learning. However, in spite of excellent design and evidence of effectiveness, school curricula were not transformed and the effort was not adopted on a large scale. It does survive in the form of a YouTube video, a book, and subsequent projects that built on the underlying approach (anchored instruction and inquiry-based learning). Notable among the recent successors to Jasper Woodbury is Marcia Linn's WISE (Web-based inquiry science environment; see https://wise.berkeley.edu/). Nonetheless, Jasper Woodbury, WISE, and many other very well-designed innovative applications of educational technology have not enjoyed the sustained success previously attributed to Sesame Street.

The remainder of this chapter will review the lessons that we might take away from previous projects and apply to emerging technologies. One should, however, not become over-enthusiastic about the potential of the current or next-generation technologies to radically transform education. Rather, such a transformation is likely to take place in small and incremental improvements over multiple generations.

## 2 A Lessons Learned Framework

To establish a framework that takes into account lessons learned from prior educational technology research, it is necessary to begin with a few reminders and definitions. While these reminders may seem obvious and quite simple, they are necessary to ensure that a clear course for sustained, systematic and systemic progress is made explicit.

### *2.1 Learning*

First among these reminders is a definition of learning: Learning involves a persistent and stable change in what a person or group of people know and can do (Spector 2015). Rather than regard learning as an event or a general approach to support learning, this definition focuses on that which will be used to determine that learning has occurred. Acceptance of this definition is fundamental to the remainder of this chapter.

### *2.2 Being Human*

Next, it is important to consider the nature of a human being—the entity in which learning occurs. In the past, it has been convenient to consider a person as a rational cognitive processor (see, for example, Anderson 1996; Simon 1981). To view a person as a rational cognitive processor does provide a basis for measuring progress of learning in terms of such constructs as declarative and procedural knowledge and the ability to solve well-defined problems. There is of course evidence to support the fundamental notions involved, such as the limitations of working memory and chunking effects as competence and expertise are developed. However, there is one basic assumption implicit in implications for the design of instruction that is not well founded—namely, the presumption of rationality. The unstated belief is that learners behave rationally. That is to say that learners (a) recognize goals, (b) can identify alternative means of attaining goals, and (c) can select an optimal path to attain a particular goal. The essence of the assumption of rationality is that learners are always driven by goals and evidence pertinent to attaining goals.

The reality, however, is that people are only intermittently or partially rational. Other aspects of a person intervene in a purely rational process. People have biases and habits that may result in selecting non-optimal solutions along the way to attaining a goal. People have moods that affect choices. A variety of individual circumstances can detract from an optimal learning path. Moreover, rationality is not entirely objective and clearly defined for all tasks and all individuals. What is perceived as a rational learning approach by one instructor or one learner may not be perceived as a rational approach by a different instructor or learner.

To make this point clear, consider a person who wishes to lose weight and improve overall body condition. In addition to diet, exercise is often the recommended solution. One person may embrace a particular diet and exercise regimen recommended by a therapist, while a different person may object to the diet for any number of reasons (e.g., dislikes many of the recommended foods) while accepting the exercise regimen. Still another person may accept the diet but reject the exercise regimen (e.g., chronic back pain prevents the person from doing many of the recommended exercises). What might the therapist do in such cases? The likely answer is that an experienced therapist is likely to recommend alternatives. That is to say that the therapist takes the client as he or she is and then responds accordingly. Personalized physical therapy is widely practiced. However, personalized learning is only beginning to become a reality.

Learners are people, too. They have biases, habits, moods, special circumstances and so on. Moreover, the goals that learners have may not be closely aligned with the goals that instructors have. For example, a history teacher may have an unstated goal of wanting learners to love the study of history in the same way that the teacher does. That goal goes beyond what can be easily measured. Many learners, however, will have a different goal, such as performing well enough on tests to achieve a passing grade and spend more time on other activities. Recognizing and respecting different learners' abilities, characters, experiences, goals, and situations is a lesson that should have been learned but has yet to be realized the design and implementation of educational systems in most places.

## *2.3 Technologies*

A technology involves the disciplined or systematic application of knowledge to achieve a purpose valued by one or more persons (Spector 2015). Technologies come and go. Consider refrigeration as a representative technology. The purpose involved might be to preserve food for future consumption. Early refrigerators were called ice boxes because there was a compartment on top to hold a block of ice and a compartment below to hold food to be kept cool. Ice boxes were replaced by gas refrigerators that used compressors to cause evaporation of a fluid that resulted in lowering the surrounding temperature. Gas refrigerators were quickly replaced by electric refrigerators using a variety of coolants, some of which had harmful effects on the atmosphere. Technologies change. Technologies change what people do, what people can do, and what people want to do. People did not want to defrost electric refrigerators, so the technology evolved to include self-defrosting refrigerators.

Now consider how computers have evolved in the last 50 years. In 1965 there were mainframe computers such as the IBM 360-30 that had an amazing memory capacity of up to 64 kb. By 1975 networking began to appear laying the foundation for the emergence of the Internet. By 1985 personal computers and productivity software packages were appearing at an increasing rate/By 1995 there were flash drives with 100 times the capacity of memory capacity of the IBM 360 and both entertainment and educational software were experiencing widespread success. By 2005 cloud-based computing and social networking were pervasive. By 2015, wearable devices were gaining interest along with cyber-bullying and cyber-attacks.

Emerging technologies are evolving in close alignment with changes in pedagogy that emphasize authentic learning. This is in part due to an emphasis of creating a competitive and productive workforce for the twenty-first century and in part due to persistent complaints of students about the relevance of the learning tasks being presented to them. Authentic learning, briefly stated, is focused on creating meaningful and relevant learning tasks—that is, learning activities that many or most learners are likely to perceive as meaningful and relevant. Since there are many differences among learners, effective support for authentic learning often requires some degree of personalization—that is, recognition of specific learner characteristics, inclinations, interests, and prior knowledge and experience. As a result, there is a great deal of emphasis being placed on personalized learning in recent years. Moreover, thanks to new and emerging technologies (e.g., context-aware devices, dynamic student modeling, learning analytics, wearable technologies), it is possible to create effective personalization in support of authentic learning activities and tasks.

This very brief sketch of changes in computing technology are included as a warning against assuming that the latest technology will still be in vogue or available in a few years. Learning designs and instructional planning should take the longer term into consideration. This warning is simply stated in the following manner: Learning is not about the technology; the technology will surely change and evolve; learning is about stable and persistent changes in what people know and can do. However, attractive and enticing the technology, we need to consider the learners—all of the learners—and the goal, which is to help improve learning.

## 2.4 Education

Educational systems are complex entities with the general goals of developing citizens with (a) basic knowledge and skills, (b) problem-solving abilities needed in everyday life, (c) skills needed to be productive workers, (d) critical thinking capacity required of responsible individuals, and (e) the knowledge, skills and attitudes to be lifelong learners. While those goals are emphasized and prioritized differently in different situations and at different levels, they appear across a wide variety of educations settings (Spector 2015).

Educational technologists have often claimed that education would undergo radical transformation on account of a new technology or pedagogical approach. Such transformations rarely happen, in part due to the complexity of educational systems and a variety of competing interests. What the workplace wants may not be well aligned with what parents or students want. What professional educators want may not align well with what can be realistically or easily implemented in schools. For example, in the USA between 2010 and 2013, an effort involving academics and professional educators from 26 states developed what are called the Next Generation Science Standards (see http://www.nextgenscience.org/next-generation-science-standards). As of 2015, 17 states had adopted (but not actually implemented) those standards (see http://www.nasbe.org/project/next-generation-science-standards/). Moreover, the National Technology Leadership Coalition through its annual Summit meeting (NTLS) has been working with just one eighth-grade science standard involving electromagnetism and concluded that while the general goal of integrating engineering into science education is laudable, it is quite difficult to implement in practice, given the breadth of the curriculum and the time available to address individual topics (see http://www.ntls.info/index.htm). One outcome of the NTLS 3-year excursion into the next-generation science standards is a project funded by the National Science Foundation in collaboration with the Smithsonian Institute and science education kits developed based on various artifacts in the Smithsonian archives (see http://www.discoverthis.com/smithsonian.html).

In short, a change that might be expected to have a very short-term impact on an educational system is likely to take years and perhaps a generation to have an impact. A major factor that is key to change in an educational system is the training and professional development of teachers, which is a generally neglected area when funding for educational technology efforts is planned. This was not a problem with the Sesame Street effort since the teaching was designed into the television shows themselves and the target learners were primarily pre-kindergarten children.

## 2.5 A Framework for Effective Change

Given the prior discussion, how might one conceptualize the effective integration of educational technology into learning and instruction? First, one might be well advised to begin with two large considerations: the learners and the learning goals and objectives (see Fig. 1). Effective technology integration requires alignment with the learning goals and the context of instruction. Because aspects of learners occur at every level in Fig. 1, and because there are many different learner characteristics and circumstances, learners are not depicted in Fig. 1. However, understanding who the learners are plays a huge role in creating or selecting appropriate information and knowledge entities and in designing effective learning activities. Goals and objectives are critical as they provide the basis for determining to what extent learning activities and experiences have been successful. Since learning necessarily involves a change in what a person knows and can do, there needs to be way to identify and assess the extent of the desired change. As before, it should be acknowledged that a particular learner's goals may not align closely with those of the instructor or those of the course. Effective teachers often make an effort to elicit individual learners' goals and to try to move them more closely to the stated instructional goals and objectives, while respecting the differences among individuals and their circumstances.

Another critical aspect and a lesson learned from prior research is the importance of formative feedback during learning activities and instructional sequences (van der Kleij et al. 2015). Providing timely and informative feedback during instruction tends to improve learning and performance. That particular aspect is missing in many of the existing MOOCs (massive open online courses), and, as a result, many of those MOOCs would be more appropriately regarded as communities rather than courses. Badges and *mini-MOOCs* are emerging to address that deficiency (Spector 2014).

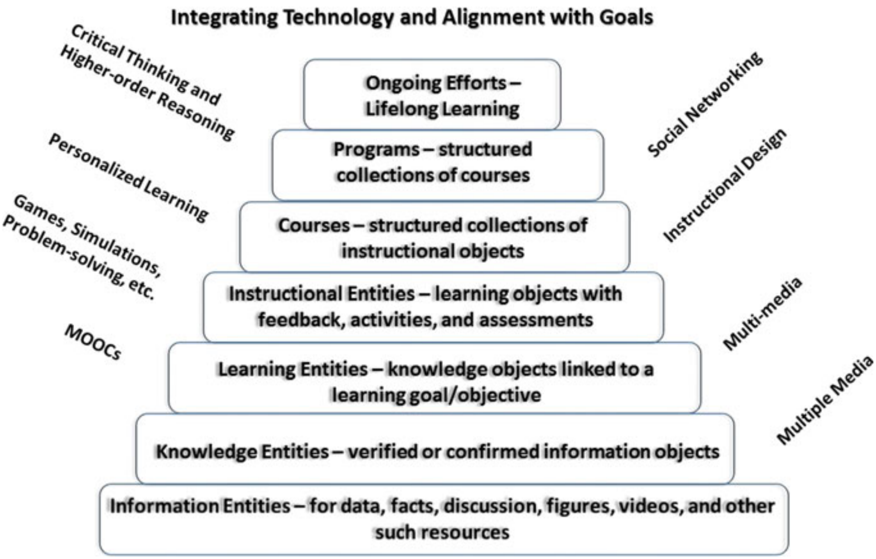


**Fig. 1** Technology integration framework (adapted from Spector 2015)

Figure 1 shows lifelong learning at the top of the hierarchy with the implication that it is unlikely that someone in the twenty-first century will become a lifelong learner without having had some success with course and programs in secondary and higher education. It is worth noting that developing twenty-first skills is not indicated anywhere in the framework (Fig. 1). The reason for this apparent omission is that these skills are presumed to permeate the hierarchy, with simpler skills (e.g., finding and retrieving information) located at the lower ends of the hierarchy and more advanced skills (problem solving and critical thinking) located in higher portions of the hierarchy. Moreover, Fig. 1 depicts the framework from an educational systems perspective and not from a learner's perspective. Nonetheless, general knowledge and twenty-first century skills rather than particular technologies should be emphasized in learning and instruction (for a comprehensive summary see http://edglossary.org/21st-century-skills/).

Finally, the framework proposes that the proper unit of analysis when determining impact on learning should include learning groups, teachers, and support personnel as well as the individual learner—that is to say that a holistic perspective should be adopted throughout. Moreover, the focus of outcomes should not be simply the declarative and procedural knowledge and skills targeted for support, but associated attitudes, collaboration skills, and higher-order reasoning abilities, again consistent with a holistic perspective.

## 3 Emerging Technologies

With the admonition that remembering important lessons learned and the framework sketched in the previous section, it is possible to examine a few of the more prominent emerging technologies and see what steps might be taken to help ensure effective integration into learning and instruction. A primary source for the relevant technologies is the New Media Consortium's 2016 *Horizon Report for Higher Education* (see www.nmc.org). Other sources to consider include Woolf's (2010) *A Roadmap for Education Technology*, *Educause Review* (see Kunnen 2015, for example), and *Government Technology* (see http://www.govtech.com/education/Researchers-Examine-Impact-of-Emerging-Technologies-on-Education.html). A selection of the technologies from those sources and how to frame effective technology integration efforts in a global context are discussed next.

### *3.1 Learning Places*

One consequence of new technologies is the impact on places where learning takes place. In some cases, mobile technologies make it possible to support learning wherever the learner happens to be located. The burden is then shifted to the learner to arrange a suitable learning space (e.g., relatively comfortable with minimal distractions). In technology-equipped classrooms, the existence of laptops, tablet devices, and smartphone make it possible to abandon previous efforts to locate workstations against a wall or in ways that inhibited collaboration. From the point of view of the framework, the learners and associated learning goals and objectives ought to be primary drivers of how learning places are arranged. If the learning goal is to gain competence and confidence in solving complex and challenging problems, then the learning place might arranged to provide access to suitable resources and support for collaborative problem solving (assuming that happens to be appropriate). Having learning spaces that are flexible and easily rearranged to accommodate a variety of learning situations is especially desirable, especially in school settings.

### *3.2 Makerspaces*

Makerspaces are places (sometimes virtual) where learners can gather, create objects, and explore alternative approaches to solving problems (see http://library-maker-culture.weebly.com/what-are-they.html). The Maker movement grew along with the growth of 3D printing. As 3D printing became more affordable, more portable, and more powerful, communities of individuals, some located with the 3D printer, began to collaborate and create, test, and implement a variety of objects. Such collaborative creative activities are well aligned with a variety of learning approaches and learning tasks, and they are part and parcel of the Smithsonian education kits previously mentioned. In a sense, a makerspace is similar to what instructional designers have been calling a design studio in which a small team gathers and collaborates in creating and implementing various learning entities and instructional support resources. A makerspace that includes more than simply fabricating an object is likely to be effectively aligned with a learning goal or objective that involves understanding and explaining (recall the eighth-grade electromagnetism next-generation science standard as a case in point).

### *3.3 Open Educational Resources*

Open educational resources are those information, knowledge, and learning entities to which nearly everyone has access at little or no cost. There are already a multitude of resources freely available on the Internet to support a wide variety of learners and learning goals. A new problem for educators is to find appropriate and reliable resources, taking into account the learners and learning goals involved locally. Some publishing organizations are assuming the role of finding and customizing those resources for schools, although this then involves a cost and a restriction to the resources archived by a particular organization. With regard to publishing, open-source publishing in education is not as prevalent as it is in the medical community. This is in part due to the fact that medical research is typically funded at a higher level with funds built into support publication and dissemination. Open-source publishing often involves a charge to authors, and this can puts graduate students and faculty at a disadvantage (recall the first principle in the Eudcratic Oath—do no harm). One significant exception is *Educational Technology & Society* which is a high-quality, refereed journal supported by the IEEE International Forum of Educational Technology & Society. In addition, Springer has agreed to make the first year or so of the open, online journal *Smart Learning Environments* free from author charges; Springer also provides free and open access to *Educational Technology Research and Development* and *Instructional Science* freely available online to members of the Association for Educational Communications and Technology (AECT). In any case, the principle in the Educratic Oath about sharing lessons with others requires some open-source venues to ensure that this happens on a large, global scale.

### 3.4 Personalized Learning

Perhaps the most promising emerging technology of all is personalized learning. In this case, personalized learning should be understood as creating customized learning recourses, activities, and sequences based on an individual learner's prior learning and specific interests and preferences. In the past, this has occurred in one-on-one, fact-to-face tutoring circumstances. It was the goal of the intelligent tutoring systems (ITS) movement in the 1980s and 1990s to do this, although the ITS movement was largely constrained by the view of the learner as a rational cognitive processor. The current personalized learning movement is firmly based on technology and aims at using learning analytics with large sets of learning and performance data and dynamic learner profiles to create specific learning activities tailored to individual learners. While personalized learning of the current variety has yet to be realized on a large or sustainable scale, it is probably the most promising of all the cited technologies in transforming learning and instruction and creating ongoing individualized educational plans for formal and informal learning at all levels of the hierarchy in Fig. 1. Learning analytics is likely to become one of the major areas of emphasis in educational technology in the next 5 years, as it can inform and facilitate adaptive instruction and other smart learning technologies as well as personalized learning.

### 3.5 Wearable Devices

Wearable devices are beginning to appear but are not yet widely integrated in learning and instruction. Devices range from simple standalone devices to measure various bodily functions (e.g., heart rate, breathing) to devices that link to other technologies to communicate back to a base device a particular state of the learner (e.g., via a smartwatch) or to send to the learner specific information for a formal or informal learning task (e.g., Google glass). These devices are not inexpensive nor are they widely disseminated and not well integrated into existing learning activities and sequences. As a result, it is worth recalling the admonition about over-enthusiasm for a particular technology. It is quite likely that these devices will begin to proliferate and evolve quite rapidly in the next five years.

## 4 Conclusion

Rather than expect rapid and radical transformation of educational systems, it is more reasonable to expect constant refinements and the ongoing introduction of new and ever more powerful devices and technologies to support learning and instruction. The technologies that can support learning and instruction are likely to change and evolve. Things not currently envisioned are likely to appear in a few short years. What is not changing is the definition of learning as involving a stable and persistent change in what a person or group of people knows and can do. It is likely that individuals will be able to learn more things faster than possible than in previous generations. Then again, there might well be more to learn as our knowledge of the universe expands. It is certainly an interesting period in which to be practicing educational technology and instructional design. The challenges are daunting, and the opportunity to gain the perspectives of people from around the globe is greater than ever before. The Chinese curse of living in interesting times (宁为太平犬, 莫做乱离人—better to be a dog in peace than a man in war) seems more like a reason to rejoice than a curse. We live in interesting albeit challenging times.

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