J. Michael Spector · Dirk Ifenthaler
Demetrios G. Sampson · Pedro Isaias
Editors

Competencies in Teaching, Learning and Educational Leadership in the Digital Age

Papers from CELDA 2014

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We dedicate this volume to the many scholars and practitioners who have demonstrated (a) that information and communications technologies have the potential to improve learning and instruction and (b) that learning and instruction have the potential to make the world a better place for everyone.

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Preface

The 11th International Conference on Cognition and Exploratory Learning in Digital Age (CELDA 2014) was held in Porto, Portugal, October 25–27, 2014. As with previous CELDA conferences, the purpose was to address the main issues concerned with evolving learning processes and supporting pedagogies and applications in the digital age. There have been advances in both cognitive psychology and computing that have affected the educational arena. The convergence of these two disciplines is increasing at a fast pace and affecting academia and professional practice in many ways. Paradigms such as just-in-time learning, constructivism, student-centered learning, and collaborative approaches have emerged and are being supported by technological advancements such as simulations, virtual reality, and multi-agent systems.

These developments have created both opportunities and areas of serious concerns. This conference aimed to cover both technological as well as pedagogical issues related to these developments. The main topics included:

- Acquisition of expertise
- Assessing progress of learning in complex domains
- Assessment of exploratory learning approaches
- Assessment of exploratory technologies
- Cognition in education
- Collaborative learning
- Educational psychology
- Exploratory technologies (such as simulations, VR, i-TV, and so on)
- Just-in-time and learning-on-demand
- Learner communities and peer support
- Learning communities and Web-service technologies
- Learning paradigms in academia
- Learning paradigms in corporate sector
- Lifelong learning
- Pedagogical issues related with learning objects
- Student-centered learning

- Technology and mental models
- Technology, learning, and expertise
- Virtual schools and universities

The CELDA 2014 Conference received 78 submissions from more than 20 countries. Each submission was reviewed in a double-blind review process by at least two independent reviewers to ensure quality and maintain high standards. Out of the papers submitted, 25 were accepted as full papers for an acceptance rate of 32 %, 17 were accepted as short papers, and 2 were accepted as reflection papers. A special issue with elaborated versions of five selected papers from CELDA 2014 along with a featured article by CELDA organizers Dirk Ifenthaler, Demetrios Sampson, and Michael Spector has been published in *Technology*, *Knowledge and Learning*—see http://link.springer.com/journal/10758/20/2/page/1.

As with previous CELDA conferences, authors of the selected best papers were invited to contribute elaborated versions to an edited volume. This book contains those contributions. The invited keynote speaker at CELDA 2014 was Jan Elen, and his contribution entitled "Reflections on the Future of Instructional Design" is the *opening chapter* (Chap. 1) in this volume. Elen addresses the field of instructional design as a technological field of inquiry aiming to build on a strong theoretical base. Elen argues for gathering unobtrusive data in actual settings and using those data to build an engineering science that can improve based on the systematic review of data and the construction of a reliable knowledge base.

The remainder of the book is divided in to four parts, each of which was edited by one of the CELDA organizers. The final chapter is a look forward authored by the CELDA organizers.

Part I is entitled "A Global Conversation About Competencies and Challenges for Twenty-First-Century Teachers and Learners," which was a featured theme of the conference. There are four chapters in the opening part of the volume that are centered around the invited presidential panel that opened the conference—that panel had the same title as this part of the book.

Chapter 2 by Lynne Schrum, Dale Niederhauser, and Neal Strudler is entitled "Competencies, Challenges, and Changes: A US Perspective on Preparing Twenty-First-Century Teachers and Leaders." That chapter focuses on the many challenges that teacher educators and educational leaders face in preparing the next generation of teachers in America. The pressures created by standards and regulations along with the rapid expansion of technologies and an evolving notion of literacy are addressed. Teacher preparation programs in universities are struggling to respond to those pressures while being less well equipped in terms of technology than many of the schools into which graduating teachers will be placed.

Chapter 3 by Rose Dolan is entitled "Initiation and Implementation: Changes to Teacher Education in Ireland" and presents a historical perspective of how Ireland has responded to the challenges and pressures discussed in Chap. 2. Ireland's Education Act of 1998 led to the formation of the Ireland Teaching Council which produced four policy documents, a revised code of conduct, and a number of documents pertaining to initial teacher preparation (ITE). While Ireland's educational system is not nearly so complex as the American system, the significance of high-level policy guidance with support and follow-through is clearly illustrated in Dolan's contribution.

Chapter 4 by Ronghuai and Junfeng Yang entitled "Digital Learners and Digital Teachers: Challenges, Changes, and Competencies" examines the influence of technology on learning and the need to properly prepare teachers. The American frameworks of pedagogical content knowledge (PCK; Shulman, 1986) and technological, pedagogical, and content knowledge (TPCK; Mishra & Koehler, 2006) are discussed in detail with regard to the need to properly prepare Chinese teachers and students in the twenty-first century.

Chapter 5 by Nicole Bellin-Mularski, Dana-Kristin Mah, and Dirk Ifenthaler is entitled "Preservice Teachers' Perspectives of School Development." This contribution involves a study of 951 preservice teachers aimed at exploring the complexity of factors influencing innovation and school development in Germany. The findings of this research study suggest that competency-based training programs focused on school development are needed. Stronger collaborations between preservice and in-service teachers are recommended, potentially supported through social networking. The need for additional empirical research aimed at the complex and multifaceted nature of schools and how they are organized, developed, and situated to respond to changing needs and technologies is made clear in this chapter.

Part II is entitled "Changing Learning and Instructional Paradigms," which was a theme that emerged from the papers presented at the conference. This part contains five chapters that cover various frameworks and strategies that have the potential to transform learning and instruction.

Chapter 6 by Sylianos Sergis and Demetrios Sampson addresses the issue of analytics and in the form of a multilevel framework to integrate and analyze data collected across different school layers so as to provide ongoing formative feedback to school leaders.

Chapter 7 by Kay Wijekuma, Bonnie Meyer, and Puiwa Lei reports the results of a study of English language learners investigating the impact of teaching five text structures along with two forms of support: Spanish scaffolding (both English and Spanish texts) and an English hybrid version that allowed students to hover over words to see the Spanish version. The results of such support were generally positive.

Chapter 8 by Norsamsinar Samsudin, REngasamy Premila, Jessnor Elmy Mat Jizat, Hariyaty Ab Wahid, and Norasibah Abdul Jalil reports an investigation of school-based assessments in Malaysia. While the level of teacher understanding of readiness to implement school-based assessments was found to be high, the study also showed a negative relationship between teacher understanding and readiness and their workload levels. This study suggested that heavy teacher workloads are a barrier to progressive school improvement in Malaysia as they appear to be in other parts of the world.

Chapter 9 by Sandra Ribeiron, António Moreira, and Christina Pinto da Silva focuses on the important topic of digital storytelling. They argue that storytelling has long held an important place in education and society more generally. Digital storytelling has the potential to address important emotional issues that can either enhance or inhibit learning. The act of telling stories can promote self-reflection and develop trust and dialogue among learners. The use of technology to support storytelling, then, has the important potential to foster interpersonal interactions that can promote social responsibility and emotional intelligence.

Part III is entitled "Assessments and Analytics for Teachers and Decision Makers," which represented a second emergent theme from papers presented at the conference.

Chapter 10 by Martha Carey and Catherine Schifter addresses the controversial issue of standardized testing in the context of the USA. They argue, as have many others, that such assessments create disadvantages for many students. Their solution approach involved providing evidence that contextually driven formative assessments can help alleviate the problems with standardized assessments.

Chapter 11 by Steve Bennett, Trevor Barker, and Mariana Lilley examines the use of electronic voting system clickers. They conducted a series of studies in a master's-level course on media design that had the entire class use clickers to provide peer feedback on multimedia resumes developed by classmates. As the methodology evolved, the notion of peer grading was replaced by free and open feedback in response to a set of standard questions about the designs. They note some resistance on the part of students and cite limitations, while pointing out that as the rubrics and scoring evolved, students became more receptive, and there are efficiencies in using this kind of feedback on student-created artifacts.

Chapter 12 by Said Hadjerrouit reports a case study involving collaborative writing in a wiki-based environment in a teacher education course on Web 2.0 technologies. There are a number of issues reviewed and examined in this study, including collaborative work in small groups, the distribution of work within a group, the role of a technology such as a wiki in supporting group work, and the value and impact of comments within the wiki. One innovative aspect of this study is that it involved using one of the technologies being examined as a tool to support course work. The author notes that a wiki-based approach to learning and instruction is not well developed and much more research in this area is required.

Chapter 13 by Timothy Arndt and Angelo Guercio focuses on student-centered analytics in postsecondary education. The motivation for their work is the difference in the interests and preferences of students (which they call do-it-yourself analytics) and those of universities and colleges (typically referred to as learning analytics). The authors present a framework for the development and implement of student-centered analytics and propose a research stream that will address the efficacy of student-centered analytics in comparison with the efficacy of learning analytics.

Chapter 14 by Peter Rich and Matthew Langton reviews the notion of computational thinking. They conducted a Delphi study to develop a consensus definition of computational thinking that might clarify educational issues and guide the development of courses aimed at promoting computational thinking. Many have promoted the notion of computational thinking as an important twenty-first-century competency, but given the variety of views about computational thinking, it is not clear what skills and competencies should be taught to whom and when. This effort is a step in helping to resolve those questions.

Part IV is entitled "Changing Tools and Learning Environments" and represents a third emergent theme from papers presented at the conference.

Chapter 15 is by Cheolil Lim, Sunyoung Kim, and Jihyun Lee. They investigate and report the impact of turning two university lecture courses (calculus and nonlinear systems) into flipped classroom courses. The results suggest that not all students liked or benefited from the flipped classroom approach. However, the studies also suggest that it is possible to design and manage a large course using a flipped classroom approach, although the design had to be adjusted to fit the particular course. Students tended to like the increased interaction with the instructor and efficiency of viewing assignments online via video-based lectures. Lessons learned from the two different implementations of a flipped classroom approach are discussed in detail in the last part of this chapter.

Chapter 16 by Lee Schlenker and Sébastian Chantelot examines a scenario-based approach for improving management education. They review the research on the use of scenarios and design thinking and use that review as the basis for the approach they call DSign4Practice (not to be confused with the Design4Practice program developed at Northern Arizona University in 1994). Their DSign4Practice framework involves a community of practice with interconnections among place, platform, and people. The notion of creating support for the co-creation of participatory learning places is fundamental to the framework. They conclude with a call to implement the framework and conduct research on its efficacy.

Chapter 17 by Leila Mills looks at the role of informal learning in developing and supporting interest and learning in science, technology, engineering, and mathematics at the high school level. She used an instrument called Possible Science Selves in a pre-/post-study of students on a field trip to the Laser Interferometer Gravitational Wave Observatory Science Education Center in Livingston, Louisiana. The results showed that students with a low desire to become a scientist prior to the field trip were significantly higher in that desire after the trip compared with those who reported a strong desire to become a scientist or who had high confidence in their academic skills. However, in general, there was an increase in reported desire to become a scientist after the field trip. She cites the limitations of the study and suggests additional studies to explore the impact of informal learning on interest in science-related learning and careers.

Chapter 18 by Cristina Gomes, Mauro Figueiredo, José Bidarra, and José Gomes examines gamification in music learning. The development of the Flappy Crab game application for mobile devices and its initial use in music education are reported. The game was developed using the UNITY 3D® game engine and initially tested informally. Results suggest that students liked the game and participated in many game-related activities. Additional studies are planned based on the positive outcomes using the prototype game.

Chapter 19 by Cindy Kröber and Sander Münster reports on the creation and evaluation of an educational application in the area of cultural heritage—in this case, the cathedral in Freiburg, Germany. The instructional approach involved project-/problem- and team-based learning at the college level with students involved in interdisciplinary studies in art history, linguistics, and geoscience. The focus of the project was on aspects of the architecture within the cathedral that had implications for communicating with visitors that could then be presented in visual form through a mobile application. Creation of such a visitor application was motivating for students and created a need to understand a number of issues in the various disciplines involved. The benefits of such applications within an interdisciplinary curriculum are discussed along with lessons learned from the effort.

Chapter 20 by Peng Yan and colleagues discusses the issues involved in designing intelligent tutors. An intelligent tutoring system developed for Virtual Cell, an educational game, is reported in terms of its use in a cellular biology course. The game contains a number of information resources which are needed to succeed in specific game scenarios. The game contains four modules: (a) organelle identification, (b) electron transport chain, (c) photosynthesis, and (d) osmosis. Initial findings suggest that students gained the desired knowledge and competencies. Additional games based on their goal-based and immersive virtual approach and framework used are suggested.

The final chapter (Chap. 21) by the conference organizers is entitled "A Synthesizing Look Forward in Teaching, Learning, and Educational Leadership in the Digital Age." In the final chapter, the authors address the need to align teacher preparation, the design and development of learning environments, evaluation and ongoing support, teaching and learning standards, and education policies. Without alignment across all aspects of an educational system, it is unlikely that promising efforts to integrate technology effectively will be taken to scale or that steady progress in learning and instruction will occur. That chapter concludes with a call for serious efforts to create dynamic, multidimensional links among educational researchers, practitioners, teacher educators, and policy makers.

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Finally, we would like to acknowledge the support of Springer Science + Business Media; Springer's education editor, Melissa James; and Springer's project coordinator for this edited volume, Michael Koy. Springer has been very supportive of CELDA for many years by supporting the publication of an edited volume based on expanded and edited versions of the best CELDA papers.

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Chapter 1
Reflections on the Future of Instructional Design Research

Jan Elen

Abstract Instructional design aims at being a *technological field of enquiry*. For such a science, it is essential that it can build on a strong theoretical base. Confronted with the phenomenon of noncompliance or instructional disobedience, it is wondered what the validity and relevance is of the current theoretical base of instructional design. This is mainly because it builds on data gathered in experimental settings with interventions of short duration and with self-reporting instruments. It is argued that new research approaches largely built on the gathering of unobtrusive data in ecological settings may help to strengthen the knowledge base of instructional design. This in turn may help instructional science to become an engineering science.

Keywords Instructional design • Theory development • Tool use

1 Introduction

Educational quality is of paramount importance to society. An important way to bring about quality is through the deliberate and systematic design of learning environments. While this sounds straightforward and evident, designing learning environments responsively and responsibly is complex. Instructional design research aims at increasing our understanding of what is important in designing learning environments and what—within a specific context—are appropriate decisions. In this contribution, some reflections are formulated with respect to the aims and scope of instructional design research on the one hand and its future on the other.

This contribution is based on two keynote presentations. The first was given at the EARLI-conference in Münich, Germany in August 2013; the second was delivered at the CELDA conference in Porto, Portugal in October 2014.

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First, it is argued that instructional design implies the practical application of scientific insights; it is in other words a technology. It builds on basic research that provides insight in learning processes on the one hand and interactions between individual learners and features of instructional environments on the other. This idea of a linking science, of course, aligns with the work of Glaser (1976) who already in 1976 argued in favor of a specific, prescriptive kind of psychology of instruction that would tune scientific insights acquired in well-defined empirical settings such as learning laboratories into instructional designs.

The instructional design research that resulted in these reflections is presented and discussed in a second part. That research reveals a phenomenon of—to put it a bit provocatively—instructional disobedience. Research evidence (e.g., Beasley & Smyth, 2004; Betrancourt, 2005) is growing that learners only rarely interact or behave as designers expect them to interact. Indeed, students neglect support provided, do not study the materials in a fixed or expected sequence, reply with shallow answers to deep-level questions, split group tasks into individual work rather than engaging in collaborative learning; learners do all sorts of things that designers view as less functional and—given current scientific understanding—as suboptimal for their learning.

Research implications of this phenomenon will be discussed in the third part. It is explored why—given the nature of the research instructional design builds upon—the phenomenon might be non-surprising. Further, research is discussed that might help both to better understand learning and instructional processes and to turn instructional design into a linking science it wants to be.

Dramatically, new insights will not be revealed in this contribution; rather, current practices will be discussed. Nothing of what is presented is new (other than a specific perspective on current practice) and the basic line of the reasoning is very familiar; that is to say that this contribution may serve as a pointed reminder of current practice and the gap that exists with regard to relevant research and theory. This reflects a conviction that instructional design research urgently needs more accumulation in order to be able to reveal what is actually new.

2 Instructional Design as a Technology

There are at least two things to be highlighted about instructional design. First, instructional design aims at the enhancement of learning in an instructional context. Instructional design is not oriented towards informal learning but towards the kind of learning that *others* (e.g., researchers, designers, instructional leaders) want to happen. The relationship between the goals of external actors and learners is a key and somewhat underestimated issue in instructional design. For optimal learning in an instructional setting to occur, it is beneficial—if not essential—that learners accept and appropriate externally recommended or imposed goals. Given this context, motivation to reach these external goals is a student variable as important as prior knowledge.

Second, instructional design is a technology that offers evidence-based guidelines on bringing about instruction. The aim of instructional design research is fundamentally practical. It offers guidelines on how to ensure—or at least optimize—learning.

It is a *prescriptive* science, providing—within a series of restrictions—the probabilistically most optimal (research-based) solution for practical problems.

Instructional design guidelines are often presented in models. Instructional design models give advice on goal-specific designs and target-specific interventions of two kinds: (1) learning tasks or interventions that elicit particular learning activities from the learner, and (2) learning support or interventions that are likely to help learners to successfully engage in those learning activities.

While instructional design models (ID-models) over the years have dramatically changed, they continue to show important similarities. It seems impossible, for instance, to identify a model that does not assume that—in order to learn—particular activities have to be engaged in by the learner. Learning activities predict learning outcomes, as noted by Skinner with his teaching machine, Gagné (1985) with his conditions for learning, Merrill (2002) with his first principles or van Merriënboer (1997) with the 4C/ID-model. Each of these models provides guidelines to elicit learning activities. While all of these and other ID-models build on that same fundamental assumption, differences among the models are significant and reflect different conceptualizations of learning goals, learner characteristics, and most importantly learning processes. Different perspectives on learning result in different views about the nature of activities to be performed to reach particular goals, assessing successful attainment of goals as well as about the extent to which particular learning activities can be—sometimes partially—supplanted (Greeno, Collins, & Resnick, 1996).

ID-models exemplify the technological nature of instructional design. In view of solving specific practical problems (designers and instructors want learners to learn something specific) instructional design builds upon basic scientific insights. For instructional design, research on learning (including motivation) and more specifically research on the interaction between environmental features and that learning are of paramount importance. Instructional design as a research discipline is directed towards investigating effects of proposed solutions in order to gradually elaborate models of effective and sustainable solutions. Instructional design, as a practice, uses these models to develop and implement concrete solutions. This is nicely illustrated by the work on the 4C/ID-model (van Merriënboer, 1997). The model is firmly rooted in basic research on learning and instruction, integrates multiple insights, provides practical advice, and generates new research questions. Given the technological nature of instructional design, it is clear that its strength depends on the solidity of the research it builds upon. This will be further discussed in the last part.

3 Instructional Disobedience or the Noncompliant Learner

Over the years, research has revealed an interesting phenomenon. Students regularly are *instructionally disobedient*; that is to say that they do not follow the paths instructional designers have outlined for them. Considering the findings, Goodyear (2000) called these *learners noncompliant*. The phenomenon can be illustrated by a variety of studies.

3.1 *Some studies to Illustrate Noncompliance*

A first study by Barbara Greene and Susan Land (2000) addresses the use of different types of scaffolds. In this qualitative landmark study, 18 college students were monitored on how they worked with Web resources and how they used different types of scaffolds. Of specific interest here are *procedural scaffolds*. As specified by Greene and Land "The purpose of the questions was to help students frequently evaluate and reflect on their project ideas by having them answer what and why questions about their current project plans in order to explain their ideas" (p. 159). Unfortunately, this is not what happened. As Greene and Land concluded, procedural scaffolds are often not adequate, partly due to omitted questions or superficial answers, indicating a failure to engage students in deep processing; rather than using questions to aid cognition, learners seemed to consider questions as impeding progress and often ignored them.

A second study is one by Geraldine Clarebout. Clarebout (2005) who asked 185 university freshmen to solve ill-structured problems in a computer-based learning environment using a wide variety of tools such as videos, background information, and planning tools. Students were distributed over three conditions: (a) a control condition with tools only, (b) a condition in which a pedagogical agent prompted at regular intervals the use of tools, and (c) a condition in which a pedagogical agent adaptively prompted tool use by considering tools already used. Achievement was measured by the quality of the proposed solution. There was only one significant result. Students in the nonadaptive advice group in which prompts were offered at regular intervals, provided more arguments for their solutions than students in the other groups. Overall, tool use was very low and surprisingly the conditions did not differ with respect to total amount of tool use. Students, however, differed in the proportion of time spent using the different tools with the most time spent on using the information tools. Results further indicate that students most of the time did not follow advice provided by the pedagogical agent.

A third study is one by Lai Jiang. Jiang (2010) studied the impact of higher order adjunct questions in instructional texts. Inspired by Rich Mayer (year), 42 university students studied a short science text on how lift occurs in airplanes. There were two conditions: (a) an experimental one with questions and (b) a control condition without questions. Questions occurred at the end of each relevant paragraph. Achievement was tested by retention and inference questions. Students in the control condition outperformed students in the experimental condition on retention questions, whereas students in the experimental condition outperformed students in the control condition on the inference questions. It was observed that students accessed the first question more frequently than the second and third questions. Furthermore, the quality of question use was studied. It was observed that some students did try to generate a proper answer whereas others simply copied information from the text into the answer field. Overall, frequency of accessing a question was not related to performance. For quality of use, results confirm the hypothesis that the higher the quality of the answers students gave to adjunct questions, the better they performed in the post-test.

A fourth study is one by Tinne Dewolf and colleagues (2012). In this study, the impact of pictures while solving word problems was investigated (Dewolf, Van Dooren, Kellen, & Verschaffel, 2012). Research in mathematical education shows that students often do not adequately model the situation as described in word problems and consequently give mathematically possible but realistically impossible answers. Given text-picture research, it was assumed that pictures would help learners to better model the situation as described in the word problem. However, no effect of pictures was retrieved. In a follow-up study using eye-tracking, it was found that the absence of effect could be due to the negligence of the pictures by the participants (Dewolf, Van Dooren, Ev Cimen, & Verschaffel, 2014). They simply did not look at the pictures. In a later study, it was revealed that they did not do so even after encouragement to do so.

These are only a few studies in a long series of research efforts that suggest four fascinating conclusions. First, though based on solid theoretical understanding and empirical evidence, outcomes of these studies were largely not as expected, in most cases they were even totally disappointing. Second, learners did not behave in line with what was expected by the designer; they were noncompliant or even disobedient. Third, in all cases participants had some degree of learner control; that is to say that they had some freedom to decide whether or not to use the support, or at least they could decide about how to use the support. Fourth, each of these studies shows that it is nearly impossible from the description of the instructional environment to predict what the outcome will be. By using components of the instructional environment, it is the learner who decides about the use and hence the effects of that environment.

From an instructional design point of view, these conclusions are very discomforting. The studies reveal that instructional design is based on the idea of a compliant learner (Goodyear, 2000), which reflects two faulty assumptions (Winne, 2004): (1) the provision of particular support will elicit the cognitive processes as intended by the designer (Gerjets & Hesse, 2004; Winne, 2004), and (2), instructional interventions will elicit similar responses among different students (Lowyck, Lehtinen, & Elen, 2004; Winne, 2004).

3.2 Explaining the Phenomenon

The phenomenon of noncompliance revealed by these studies is well documented and several researchers have tried to explain it. Perkins (1985), for instance, proposed three clusters of factors that affect whether a learning opportunity will be effective: (1) the opportunity has to be actually present, (2) the learner has to be knowledgeable about it, and (3) the learner has to be motivated. These factors are discussed next.

First, availability of opportunity pertains to the question whether the actual use of the tool, support device, or adjunct aid does indeed improve learning. This calls for a particular type of research since we need a situation that guarantees students to adequately use the tool and moreover allows us to observe learning effects (performance or motivation) at least for particular groups of students. Typical for instance is the mostly experimental, research on advance organizers showing a (conditional) benefit of adjunct aids (Mayer, 1979). While for most support devices in instructional texts *availability of opportunity* has been researched, far less evidence in this respect is available for a multitude of tools provided in current electronic learning environments such as links to ample resources and discussion for all kinds of illustrations. There is certainly a need for basic instructional research on the actual functionality of the enlarged set of support devices.

The second and third condition of Perkins are research-wise more difficult ones, and the research base seems far less stable. The second category pertains to knowledgeability of students. Students have to be knowledgeable about the tool's usefulness. Illustrative is the classic study by Gavriel Salomon in 1984. Salomon asked 124 sixth graders to study a comment on abstract art either in a film version or a printed version. Much care was invested in making both versions as informationally equivalent as possible. Achievement was tested by using factual recognition and inference questions. In addition, a number of instruments was administered with respect to perceptions of media, attribution of failure, perceived self-efficacy and, after the session, invested mental effort. It was found that while doing equally well for the factual recognition items, students in the print group performed much better on the inferences part of the achievement test. Salomon explained these results by referring to perceptions of students. Students considered learning from film to be easier and hence invested less effort while studying. The opposite was true for the print condition. More effort was spent because students regarded studying from print to be difficult. This finding supports the established notion that time spent on a learning task will be correlated with the associated learning outcome.

Research suggests that in order to learn in an instructional context learners not only need knowledge about their own learning but also and specifically about how elements of the environment can be used to support their learning. Two elements hamper research on these matters. First, attempts to solidly assess instructionally relevant conceptions, beliefs, and perceptions have not been very successful. In our own work, we have elaborated a highly reliable instrument—the instructional conceptions questionnaire—but despite repeated attempts, we have never been successful in demonstrating any direct or indirect impact of these conceptions on actual tool-use behavior (reference citation needed here). Second, there is a problem especially with survey instruments as they largely neglect the volatility of perceptions. Lust and colleagues (Lust, Elen, & Clarebout, 2011), for instance, assessed perceptions of students about Web-based lectures and found a significant difference in the perceptions at the start and at the end of the semester. Perceptions seem to be easily modifiable.

Perkins' third category specifies that the learner has to be motivated to use the opportunity. In various studies, attempts have been made to include motivational variables in order to find some clear links between motivation and tool use. The results are at least inconclusive. In various studies, conflicting results have been found. For instance, in line with research by Ryan and Pintrich (1997) one may expect a positive relationship between mastery goal orientation and tool use. While in a study by Jiang and colleagues (Jiang, Elen, & Clarebout, 2009), some indications were found that point in this direction; in another study, Clarebout and Elen (2009a, 2009b) found a negative relationship between mastery goal orientation and quantity of tool use. Again, for motivational variables there are conceptual as well as methodological problems. It is highly difficult to use motivational literature for design purposes.

Keller's (2010) theory of motivation attempts to relate motivational variables (e.g., attention and volition along with perceived relevance, confidence, and satisfaction) to different stages of the learning process, but it remains somewhat vague and general. There are also methodological issues. Research that includes motivational variables heavily (though not solely) relies on survey instruments. In addition to the issue of self-reporting, we are confronted with a time issue as it is plausible to expect motivation to fluctuate over time.

While Perkins' conditions help to understand the phenomenon of instructional disobedience, consensus is missing on how to handle it. Some designers argue for additional interventions while others favor restricting the degrees of freedom. Research is not conclusive. Prompts are examples of additional interventions (e.g., Schwonke et al., 2013). Again the results are not very convincing, partly because it is assumed that indeed the prompts are adequately considered and followed up by the learner which is certainly not always the case. Research on prompts typically assumes a compliant learner, a presumption assumption that has been proven to be overly optimistic. Embedding the interventions is another possibility. One thereby reduces the amount of freedom for the learner. The learner has to try to process the material as indicated. Interestingly, research by Jiang (2010) among others shows embedding has a serious impact. On the one hand, embedding results in an increased (because unavoidable) use of the support, while on the other it tends to reduce the quality of tool use.

4 Features of Instructional Design Research

Research on tool use and noncompliance is intriguing as it reveals that we might be missing an in-depth understanding of actual learning processes in instructional contexts. Research on disobedience or noncompliance clearly shows that instructional environments informed by the best possible basic research do not generate expected effects. To put it in medical terms: drugs tested in the lab do not necessarily cure the illness.

4.1 Issues with Respect to the Research Base

There might be at least two categories of reasons for that: (a) the design itself might be defective or (b) the underlying research is insufficiently adequate. The latter will be focused on next. In three different ways, it might be that the research base is insufficiently adequate.

First, a substantial part of the research is [quasi-] experimental. This type of research might help us to find out whether a particular type of support is effective, which means: results in increased motivation and/or enhanced learning outcomes. Given the need to control as many variables as possible, that research is also intrinsically limited. Examples are research on multimedia learning in which students can look at a video only once or cannot reread a specific part of the text, or research on pre-questions in which students during reading cannot re-consult the questions. There are good reasons for these restrictions as they help us to reveal underlying cognitive structures and processes. But at the same time, these restrictions also reduce the relevance of the findings with respect to the instructional interventions. While a very strict control of time might be relevant to reveal the impact of the limitations of working memory, that same restriction renders this research instructionally nearly irrelevant as such a strict time limitation is commonly absent in instructional contexts. In most instructional contexts, learners do have much more control and that control pertains to a multitude of dimensions. Learner control is not a side-issue, but a key feature of learning in instructional contexts. Research on how learners handle that control, or in other words how they regulate their learning in realistic learning settings might therefore be even more important than already recognized in instructional design.

Second, another typical feature of much of the research is the short duration of the interventions. Though there are good reasons (control of variables) and less good reasons (e.g., publication pressure) for this, it seriously affects understanding of how to support learning in instructional contexts. In actual instructional contexts, multiple topics are discussed and given that they cannot all be addressed at the same time, they are handled in some sequence. Experiences at the start affect consecutive actions and information provided later may help to understand information presented previously. This reveals the importance of research on sequencing. Luckily, studies that handle sequencing do appear from time to time, as in the context of cognitive load theory (van Merriënboer & Ayres, 2005). It also seems fair though to say that, overall, our understanding of duration and sequencing has not progressed much in the last 50 years. In any case, the issue of sequencing reveals the relevance of models such as Patricia Alexander's (1993) model of domain learning by or the research on learning progressions (Fortus & Krajcik, 2012). Both approaches handle evolution and multiple concepts.

A third aspect of the research that we build upon involves the use of questionnaires. Survey instruments are used to identify the learning style of students, their motivation, and their perceptions. In other words, a lot of what we understand is based on self-reported information. We are gradually becoming aware that this research is based on two rather problematic assumptions. A first assumption, recently called an *urban legend* by Kirschner and van Merriënboer (2013), is that students not only know what they prefer but also what and why they behave or what is best for them and their learning. Research by Hadwin and colleagues (Hadwin, Winne, Stockley, Nesbit, & Woszczyna, 2001) and others clearly demonstrate that this assumption is at least naïve and that—as my professor of social psychology used to stress—behavior and talking about that behavior are two different behaviors that each need to get explained in their own right since they are not intrinsically related. The second assumption is equally problematic and relates to the assumption of stability over time. This is a complex issue but there are at least indications that perceptions about the effectiveness of instructional interventions or methods do change with growing experience with these methods as previously illustrated.

4.2 An Engineering Science

Given this status of the instructional design knowledge base, it is not totally surprising that designs are less effective than expected. However, the time seems ripe and the methodologies seem to be available to render the knowledge base more solid and to gradually convert instructional design research from a direct application science into an engineering science (Goodyear & Ellis, 2008). Such an engineering science gets inspired by basic research in a creative quest for solutions rather than trying to directly applying the outcomes of basic research to actual practical problems.

Instructional design research seems to gradually acquire the tools and the insights to refocus and put another step in the direction of instructional design that builds on ecological research that is directly practical. We now have the possibility to open the black box (or boxes) of learning in instructional settings. Disobedience may be shown not to be the exception but the rule, and a key to progress in learning is self-regulation.

The new tools are directly related to the increased use of electronic learning environments and the possibility to unobtrusively log and analyze actual learning behavior. There is great hope that this research—be it under the umbrella of gStudy, an approach by Winne and colleagues, that closely monitors the self-regulation of learning activities (Hadwin, Oshige, Gress, & Winne, 2010), learning analytics, or educational data mining—will help to get in the long run a far better understanding of learning in instructional contexts (Angeli & Valanides, 2013).

In the past, observational studies were done, some with thinking aloud. Based on these observational studies, it is now better understood how for instance problems are solved and texts are processed. What is new is that we now in real instructional contexts can observe what larger populations do and not only what a few students do.

The following example may reveal both its potential and its restrictions. In a recent series of studies, Lust (Lust, Elen, et al., 2011; Lust, Elen, & Clarebout, 2012, 2013; Lust, Vandewaetere, Elen, & Clarebout, 2014) logged and analyzed, for one particular blended learning course, students' use of a large set of tools. Based on her data, she did various things.

First, she analyzed the frequency of tool use and looked for patterns. In two consecutive studies with the same course but different student cohorts, similar tool-use patterns were retrieved. Each pattern reflects diversity in tool use and/or the nature of that use (more or less active). With respect to tool diversity, cluster analyses revealed three groups of students: no-users, selective users, and intensive users. No-users only accessed one particular component of the electronic learning environment: the Web-lectures. Selective users did only access information and scaffolding tools with immediate functionality. Intensive users accessed all tools although with respect to the intensity of the use large intra-group variability was ascertained. For instance, whereas some intensive users read messages on a discussion forum others also add comments or raise questions.

While, with respect to tool use, these data are interesting, more can be done. Lust tried to link patterns of tool use with performance data. In this case, performance data related to an assignment during the academic year and a final exam. While relationships are complex, overall, it can be said that no-users did not do very well and less well than intensive users for the total grade and the assignment. This is at least a relief as it confirms that indeed engaging in a diversity of learning activities (different activities with different tools) does pay off. But even this information is rather general.

That is why a third step was made in the analyses. An attempt was made to model tool use over time. We wanted to know whether students' tool use does evolve over time and whether this possible evolution is related to changing requirements in the environment. In general, an evolution in tool use can be observed with clear differences for different tools. For instance, use of Web-based lectures is very high during the cram period right before the exams. Furthermore, some students stick to a particular tool-use pattern throughout the course, whereas others change their tool use over time. For instance, whereas 29 % of the initial *no-users* remained *no-users*, 55 % of them increased their use and became *limited users*. Again the profiles of tool use over time and the changes in tool use can be linked with performance data. These analyses show that for only a minority of the students the adaptation was beneficial. Only a small part of the students succeeded to adapt their tool-use pattern to the requirements of the course. Interestingly, a small group of students who changed their tool use in line with course requirements did significantly better on the higher order learning tasks at the exam and this even after controlling for general ability.

The next question then became whether tool use (as an indicator of learning activities) could be linked to or even predicted by data gathered at the start of the course through questionnaires. Several findings are of interest here. First, this study again found that students' ideas at the start of the course about functionalities of the tools did not affect tool use. Whatever the reason and given the qualities of the research instrument used, this is another indication that students only have limited knowledge of the tools' functionalities. Furthermore and with respect to motivational variables, results were diverse.

Whereas no effects could be retrieved of students' self-efficacy on tool use, goal orientation seemed to affect tool selection: selective users were significantly more performance-oriented, whereas intensive active users were significantly more mastery oriented. This suggests that some motivational variables might be more stable than others, an important insight for instructional design research. In the study, the Inventory Learning Styles was used to identify different study approaches. Results are rather inconsistent, whereas the results obtained with the questionnaire reflect the tool-use patterns in some cases, tool-use patterns are in two other cases in contrast to what could be expected. Results revealed that the intensive active tool-use pattern reflected a strong self-regulated strategy, whereas an intensive superficial tool-use pattern reflected a lack of self-regulation. However, for *no-users* no specific profile of study approaches could be retrieved and selective users reported surface as well as deep-oriented approaches. The lack of stability raises doubts about the usefulness of this type of instruments.

We are well aware that multiple questions remain. Among these are the following: (a) are these findings course specific? (b) what is a fruitful way to describe courses? (c) are the findings specific to this population? and, perhaps most interesting, (d) how can we alter nonadaptive patterns and profiles? Intervention and replication studies have not yet been done, and meta-analytic studies are needed to advance knowledge and understanding in this area.

5 Conclusion

The potential of research largely based on actual user data has been illustrated by referring to the work of Lust and colleagues (Lust et al., 2013, 2014; Lust, Juarez Collazo, Elen, & Clarebout, 2012; Lust, Vandewaetere, Ceulemans, Elen, & Clarebout, 2011). Of course, similar work from fellow researchers such as those in the group of Phil Winne (Hadwin et al., 2010) at Simon Fraser University could also have been used as an illustration.

Notwithstanding the remaining issues, this line of inquiry shows an interesting path for complementing current instructional design research. The path more or less looks as follows:

1. Inspired by basic research, a theoretical model is built that fits the goals of the instruction and the setting in which it will take place. That model specifies the variables that play a role and why, and highlights and explains interactions between student and environment-related variables as well as the effects of these interactions over time.
2. Using the structural components of the model, a specific instructional environment is described, and aspects to be observed are identified. Hence, we get a model-bound description of a specific instructional environment.
3. Next, by using log data as well as data on those variables that were assumed to be theoretically relevant an analysis of the environment can be made. At least the following interesting questions can be raised: what learning activities were engaged in, did they fluctuate over time, what patterns were productive and are these related to students with particular characteristics. What students do not reach the learning goals within the specific learning environment and what is the nature of their learning path?
4. Inspired by the theoretically most sound and empirically most valid evidence, the environment can then be adapted and a new research iteration could be started. Enhanced success can be considered to be a validation of the theory; failure to do so constitutes a falsification and hence the need to revise the initial theory.

This type of research is necessarily practical (real-life settings are studied with real students and authentic instructional goals) as well as theoretical. This approach forces researchers in instructional design to be very explicit about the theoretical background they use. In the absence of even contradicting theoretical ideas about what variables to look at, what interactions between learner variables and components of the environment are to be expected, what changes in tool use are probable over time and which ones are desirable, there is no possibility whatsoever to analyze and/or interpret the large amount of unobtrusively collected data. Also interesting is the challenge to elaborate theories that are explicit about relationships between multiple variables and about possibly changing interactions over time. In other words, such an approach strongly induces accumulative efforts in theory building.

As indicated, this type of instructional design research has a specific relationship with basic research on learning. Given that the unit of analysis in this type of instructional design research is far larger than the unit of analysis in [quasi-]experimental research, there cannot be a direct application of the insights. Hence, multiple insights serve as inspiration to build the initial theoretical model. Similarly, basic research provides the ideas for revising the environment. Each time there is a need for unique theorizing, there is a need for establishing the link.

Confronted with instructional disobedience or noncompliance not as an exception but as a regular practice, instructional design researchers are encouraged to be critical about their current insights and approaches. Learners do not comply, not because they are disobedient, but because they are forced to do things that do not fit into the flow of their learning, a flow that is simply might not yet sufficiently understood. Not only are goals enforced upon them as a key feature of learning in instructional contexts, specific ways of learning are also imposed upon them. It is as if we would like the water to stream upwards to ensure irrigation. That won't work, not because the water is disobedient, but because the irrigation system is faulty: one that is built on invalid, over-generalized theoretical assumptions.

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Part I
A Global Conversation About Competencies and Challenges for Twenty-First Century (Presidential Panel)

Chapter 2
Competencies, Challenges, and Changes: A US Perspective on Preparing Twenty-First Century Teachers and Leaders

Lynne Schrum, Dale S. Niederhauser, and Neal Strudler

Abstract This chapter articulates the challenge that educators, school leaders, and teacher educators face today in preparing learners for their future, given the reality of students' and teachers' lives today. It then provides a US perspective on teacher and leader preparation, specifically related to the use of ICT and goals of preparing individuals for twenty-first century expectations. It explores the pressures, issues, regulations, challenges, and goals of preparing educators and leaders for the schools our students need. Through a review of the extant literature and current trends, readers will gain knowledge of best practices and recommendations for future steps.

Keywords Twenty-first century schools • ICT • Teacher preparation • School leadership

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1 Introduction

Around the world educators, policy makers, and others are seeking best practices to prepare educators and leaders to improve student outcomes, prepare learners for their futures, increase student engagement, and integrate learning technologies into their curriculum; a universal goal is to ensure that all learners reach their full potential. Questions have been raised regarding the value of child-centered pedagogy, appropriate curriculum, and role of technology in this preparation. And yet, after thirty-plus years of effort aimed at integrating technology into US schools, Fullan (2013) stated, "It is now time for technology to join the fray in a more purposeful way in order to transform learning for educators and learners in the 21st century" (p. 3). The discovery and sharing of this "purposeful" way will require many educators to work together, share lessons learned, and invest energy in promoting policies to bring about changes (Schrum & Levin, 2015).

The students in our classrooms today are the first to have grown up with digital tools at their fingertips; students interact with information, create knowledge, and communicate their results to a real audience. Today's students grew up in the digital age and have never known a world without the Internet, cell phones, video games, on-demand videos, and portable computing devices. They use digital devices daily, and most have never known a time when information was not available from Google (Hatch, 2014). The tools are always "on," accessible anywhere there is Internet access, and many are collaborative. These learners have an expectation that their education will include the same authentic, relevant, and interactive characteristics. And yet, despite the long-standing potential of technology as a catalyst for transformative change in education (David, 1991, 1994; Sheingold, 1991); this ambitious goal has yet to be widely realized. Relatedly, Fullan (2013) shared the results of a study that found satisfaction with school to be 95 % in Kindergartners but only 37 % in ninth graders; the question then must be asked if schools and our educational curricula are truly preparing learners for their futures. Additionally, in a world of globalization and rapid technological change, schools must enable and require that students develop twenty-first-century skills, such as critical thinking and problem solving, communication and collaboration, and creativity and innovation, in order to be well prepared to live and work in the twenty-first century. Being literate in the twenty-first century requires more than knowing how to read, write, and compute. The Partnership for 21st Century Learning (2015) suggests the need for infusing information literacy, critical media literacy, and information, communication, and technology (ICT) literacy into every subject taught in schools. All these new literacies are necessary to survive and thrive in the twenty-first century. Without these skills, and others—such as visual literacy, multimedia literacy, and cultural literacy—our students will not be able to adapt to changes coming their way.

An Organization for Economic Co-operation and Development (OECD) study concluded, "People who do not master these competences may suffer from a new form of digital divide that may affect their capacity to fully participate in the knowledge economy and society" (2010, p. 2). OECD further stated, "A second digital divide separates those with the competences and skills to benefit from computer use to those who do not. These competences and skills are closely linked to students' economic, cultural and social capital" (p. 2). For these and many other reasons, it is important that all schools investigate ways to provide access to each and every learner; this goal can only be accomplished by preparing current and future educators, and school leaders, for this new reality. Unfortunately, as Senge, a prominent theorist on organizational change, reminds us, "The fundamental flaw in most innovators' strategies is that they focus on their innovations, on what they are trying to do—rather on understanding how the larger culture, structures, and norms will react to their efforts" (Senge et al., 1999, p. 26).

Educator preparation and professional development programs are struggling to assist individuals in gaining knowledge and skills in these areas and the exemplary programs and ideas are worth sharing as best practices. Fullan has written that

> The question for the field of education is how it can best participate in this rapid learning cycle while working in an otherwise less and less functional system. The general conclusion for me is that this will be a messy period in which the best stance is to become a reflective doer and learner. One way of cutting this is to think of working simultaneously on continuous improvement and on innovation. (2013, p. 26)

Recent research by Kozma (2008) made it clear that several nations are currently well out in front in terms of national ICT policies. According to Kozma, national policies tend to be established based on four major rationales: (1) support for economic growth, (2) promotion of social interaction and development, (3) advancement of education reform, and (4) support for education management. The work of these countries who have established policies can serve as a model to others working to establish such policies. For example, Singapore has a long tradition of linking education policy to the economic system and the country's latest ICT Master Plan provides a good example of this approach. Jordan is a second nation that has clearly linked its national ICT plan to establish a knowledge economy. Emphasizing the social impact of ICT is a rationale especially attractive to developing countries and work in Chile provides a good example of policies emphasizing access in rural schools. Australia and South Africa both provide good examples of countries where national ICT policy is focused upon issues advancing educational reform. Finally, several countries have included policies based on the use of ICTs for management issues such as assessment and student attendance data. More recently, efforts around requiring coding in secondary schools (e.g., in 2015 Arkansas passed a law requiring all high schools to offer classes in computer science beginning with the 2015–2016 school year), and the spread of the Makerspace and Fab Lab efforts in school and in more informal settings can be documented (Schrum & Levin, 2015). Locations across the USA and other countries are becoming "education innovation clusters" in which people in a city or region pool their knowledge, best practices, and assets to improve education through technology and research (see: http://www.digitalpromise.org/).

2 The Human Element: Professional Development for Teachers

Despite 35 years of claims that technology will transform US classrooms (cf., Papert, 1980; Sheingold, 1991; Skinner, 1984), and massive financial investments, with overall instructional technology spending topping $13 billion worldwide in 2013 (Nagel, 2014), widespread well-integrated use of instructional technologies remains unrealized—underutilized by teachers and students alike (Ertmer & Ottenbreit-Leftwich, 2010). Perhaps the most compelling rationale for this shortcoming is a marked lack of meaningful professional development to prepare teachers to effectively integrate the technologies that have been installed in their classrooms into their instructional practices (Niederhauser & Stoddart, 2001; Office of Technology Assessment (OTA), 1988; Office of Technology Assessment, 1995; Project Tomorrow, 2008). These interactions among teachers, learners, technology, and support systems clearly represent a complex problem (Cox et al., 2013). Even with ongoing calls for an increased focus on preparing teachers to effectively integrate the use of instructional technologies into their pedagogical practices, the primary focus has been on procuring hardware, software, and infrastructure. Two important series of reports chronicled the infusion of technology into US schools during the 1980s and 1990s. The first were produced from data collected using National Surveys of Instructional Use of School Computers and US contribution to the international Computers in Education survey. The second set of reports was developed by the Office of Technology Assessment.

The report from the initial National Technology Survey focused primarily on the number of microcomputers available in schools, major uses of school microcomputers (primarily programming and drill-and-practice), amount of time students spent using computers, and location of microcomputer in the school (lab versus classroom) for 1580 elementary and secondary public, private, and parochial schools during the 1982–1983 school year (Becker, 1985a). The second report (approximately 7700 respondents covering the 1985–1986 school year) continued in this vein, reporting on access to hardware, which teachers used the technologies, allocation of computer time (computer-assisted instruction, programming, word processing, etc.), number of students involved in computer use, and relative use broken out by gender and ability (Becker, 1985b).

Continuation of this work through the US contribution to the Computers in Education survey conducted by the International Association for the Evaluation of Educational Achievement (Becker, 1991), resulted in a report that focused on the number of computers in US schools and noted shifts in how teachers were using them (away from programming and drill-and-practice and toward more productivity-based uses like word processing). Despite the fact that findings from these studies indicated that “teachers rarely used computers as a regular means of providing students with instruction or practice in traditional school subjects” (Becker, 1991, p. 386), researchers did not seem to acknowledge the importance of in-service training efforts that might have supported teachers in more fully integrating technology use in meaningful ways. Although these reports were central to large-scale research efforts on the emerging instructional technology movement in US schools, the focus was on easily measurable variables like the number of computers, printers, network connections, etc. in schools, the location of computers, and how the computers were being used. Essentially no attention was given to how we were preparing teachers to use the technology that had been installed in their classrooms in the National Survey of Instructional Use of School Computers or the Computers in Education Survey.

Written "less than a decade [after] the first computers appeared on the education scene" (Office of Technology Assessment, 1988, p. iii), *Power On*! *New Tools for Teaching and Learning*, the first OTA report (1988) indicated that for the 1986–1987 school year a sample elementary school had spent 13 % of the total "computer use" budget on staff development (mandatory and optional workshops to support the district-developed curriculum). For the 1987–1988 school year, staff development funding had dropped to just 6 %. This may have been due to the fact that "…many districts have very limited funds available for in-service training in general; many also have limited facilities, resources, and expertise to prepare teachers to use technology." (p. 19) Further, much of the training teachers received focused on learning *about* computers rather than learning how to teach *with* computers.

In the second Office of Technology report on instructional technology, a key finding was that "Most teachers have not had adequate training to prepare them to use technology effectively in teaching. Currently, most funds for technology are spent on hardware and software. . . On average, districts devoted no more than 15 % of technology budgets to teacher training." (1995, p. 21). After concluding that "A majority of teachers report feeling inadequately trained to use technology resources, particularly computer-based technologies," (p. 129) this report provided a clear call for increased training efforts to support teachers—describing several funding initiatives and models for providing effective professional development that went beyond "treating technology as a compartmentalized subject, or an end in itself (e.g., providing teachers with a computer 'class')" (p. 234) while acknowledging that the focus continued to be on teaching teachers *about* technology rather than helping them learn how to teach *with* technology. The nature of professional development in general, and the specific challenges associated with helping teachers integrate technology into their established practices came under scrutiny as educational policy makers began to recognize the importance of professional development as a key component in their educational technology investment.

However, Schrum (1999) has pointed out that teacher professional development for technology is particularly challenging—and that all forms are not equally effective. Her review of relevant literature suggests that professional development for technology takes considerably longer than professional development for other instructional and curricular innovations, requires access to equipment at home and at school for extended practice and to build comfort, is often more intimidating than professional development for other purposes, makes participants feel uncomfortable with technology and fearful of looking foolish, and often requires educators to reconceptualize the ways in which they have completed common tasks for many years. Further, training workshops are often held in computer labs that take teachers away from the comfort of their classrooms, and technology training tends to be "just in case" learning rather than "just in time" learning—like teaching a group of teachers how to use a spreadsheet program just in case they ever want to use it.

Despite the form professional development might take, and the amount of professional development that teachers receive, formal professional development appears to have been less successful than simply allowing teachers to learn on their own. A 2000 *National Center for Educational Statistics* (NCES) report confirmed concerns raised about teacher professional development for teachers when they stated that only 33 % of surveyed teachers felt they were "well" or "very well" prepared to use technology with their students (Parsad, Lewis, & Farris, 2000); while a 2010 NCES report (that did not report on teacher preparedness) indicated that 2/3 of US public school teachers in the sample had received less than eight hours of in-service training for using technology with their students, and 78 % had indicated that a "moderate" or "major" extent of their training had been through "independent learning" (Gray, Thomas, & Lewis, 2010). Thus, our efforts to prepare teachers to successfully use technology with their students appear woefully inadequate.

Current one-to-one initiatives (whether laptops, tablets, smart-phones, or other) will likely compound this problem as teachers, who had previously been charged with taking their students down to the computer lab once a week, or bringing a laptop cart into the classroom for the occasional project, now have constant access, and accompanying heightened expectations, that provides opportunities for them to use technology with their students all day every day. Unfortunately, teacher professional development workshops in one-to-one initiatives (often given by the vendor who received the district contract for the devices) typically focus on providing teachers with the skills they need to use the technology themselves (Penuel, 2006), while teachers typically feel the need for training and support that will help them use technology effectively in their day-to-day teaching (Davies, 2004; Fairman, 2004; Niederhauser & Schmidt-Crawford, 2013). As Collis (1996) pointed out, the teacher ultimately shapes the success of any computers-in-education initiative. If we continue to focus on simply installing technology in classrooms, without preparing and supporting teachers to use it effectively with their students, it seems unlikely that we will ever realize the potential of technology to help us reach our transformational goals.

3 Student Learning, Assessments and Twenty-First Century Skills

One key factor in the proliferation and accompanying setbacks of technology in schools involves the goals for technology use and the assessment of student learning. Early on, computers in the classroom began with a combination of bottom-up excitement by innovative teachers and top-down adoption by administrators seeking to implement visible, innovative practices. For more than three decades now, schools have adopted the goal of ICT integration for a wide range of reasons. The most consistent rationale has been tied to a sense that technology is the "way of the future" and schools need to prepare students for a technology-rich world. That general argument included the need for students to be skilled in the technical aspects of using ICT required in the work world as well as to be fluent in their ability to search for, gather, and critically evaluate information (Partnership for 21st Century Learning, 2015). These goals have been widely embraced and have permeated standards for learning across subject areas and grade levels.

In addition, there has been broad support for the use of technology to support a full range of curricular goals. And while virtually all have supported the *technology is the future* rationale, there was much less agreement on how to apply technology to address curricular goals. While some called for computers to be used as cognitive tools for students and teachers, others sought to develop computer-assisted instruction to assess and develop basic skills. Many argued that ICT has the greatest potential to enhance student learning when part of innovative, reform-minded teaching (Becker, 2000; Ertmer & Ottenbreit-Leftwich, 2010; Kozma, 2003; Sandholtz, Ringstaff, & Dwyer, 1997; Wenglinsky, 1998, 2005) while others sought to promote instructional systems that reduced or minimized the role of the teacher in the learning process. Suffice it to say that while schools were purchasing computers in unprecedented quantities, there was no clear consensus about the pedagogical approaches that would support their optimal use.

One effort to illuminate issues of pedagogy and technology were presented in *Plugging In*: *Choosing and Using Educational Technology* (Jones, Valdez, Nowakowski, & Rasmussen, 1995). Jones and his colleagues posited that the intersection of two continua—learning engagement and technology performance—could be useful in analyzing technology practices that support student learning and help educators ensure that their use of technology would complement student learning goals. In this framework, learning is represented on the horizontal axis and progresses from *passive* at the low end to *engaged* at the high end. On the vertical axis, technology performance is represented from *low* to *high*. Thus, the framework provided a second dimension to the low-tech to high-tech continuum that consumed both educators and the public alike. Among other things, the *Plugging In* framework was particularly useful for staff developers to help identify pedagogical issues and practices associated with various applications of technology.

Subsequently, a framework for technology integration, Technological, Pedagogical, and Content Knowledge (TPACK) (Koehler & Mishra, 2008; Mishra & Koehler, 2006) has gone viral in the field of technology and teacher education. Based on Shulman's (1986) idea of Pedagogical Content Knowledge (PCK), TPACK adds technology to the equation and focuses on the interplay of three primary forms of knowledge: Content (CK), Pedagogy (PK), and Technology (TK). A key contribution of the TPACK framework to the field has been its emphasis on pedagogy involved in effective technology integration. TPACK has provided a common lens and vocabulary that highlights pedagogy as a key variable in learning with technology. In fact, many have adopted TPACK as a rationale for promoting constructivist-oriented pedagogies to support optimal technology integration. It should be noted, however, that the TPACK framework is by definition pedagogically neutral, encompassing a full range of approaches across the component forms of knowledge.

3.1 One-to-One Computing

Issues of technology advocacy and accompanying pedagogical approaches have been illustrated by the proliferation on one-to-one projects. One early, high profile project was the Apple Classroom of Tomorrow (ACOT), which was conducted at multiple sites for a decade beginning in 1985. ACOT researchers sought to turn the clock ahead by providing two computers for each student—one for the classroom and one for home. Laptops, let alone mobile devices, were not viable options at that time. In studying the impact of ubiquitous computing, they found that technology-rich learning environments tended to evolve from traditional practices toward fundamentally different forms of interactions among students, involved higher level cognitive tasks, and led to constructivist-compatible beliefs and practices among participating teachers (Sandholtz et al., 1997). They observed "text-based curriculum delivered in a lecture-recitation seatwork mode is first strengthened through the use of technology and then gradually replaced by far more dynamic learning experiences for students" (Dwyer, Ringstaff, & Sandholtz, 1991, p. 47).

The ACOT program paved the way for a myriad of one-to-one projects that have since followed. In virtually all of these, the commitment to using innovative technologies far exceeded any clear agreement on how they should be implemented. In a comprehensive synthesis of research on one-to-one computing initiatives, Penuel (2006) found that while students consistently increased their technology literacy and skills, what is less clear is "what the potential is for one-to-one initiatives to improve student achievement in core subjects" (p. 341). He continued that few studies tested the links between identified outcomes and different implementation measures. In fact, he added, "a number of studies in the synthesis did not clearly specify the overall goals of the initiative they were studying" (p. 341).

Today, one-to-one programs proliferate using tablets, netbooks, and other mobile devices. While outcomes pertaining to student engagement and twenty-first century skills remain consistent, outcomes pertaining to student achievement in core content remain uneven. Many would argue that this discrepancy could be directly tied to No Child Left Behind (NCLB), the US educational policy initiative that shaped accountability measures in US schools and directly impacted the fate of technology-based reforms.

3.2 NCLB and Standardized Assessments

While it's beyond the scope of this chapter to detail the impact of NCLB, many would agree that it is at direct odds with technology-enhanced, student-centered learning. Educators have argued that standardized assessments in the USA have focused on discrete knowledge and skills at the expense of deep content knowledge, higher order thinking, and problem solving and that revisions in the testing process are needed (Darling-Hammond, 2010; Ravitch, 2010; Wagner, 2010).

As we've been pushed by federal policy to *leave no child behind*, we've ironically created another achievement gap—the gap between what is emphasized in standardized assessments and the skills most needed for the twenty-first century (Wagner, 2010). In many cases, progressive educators who have embraced the potential of technology to enhance teaching and learning have had to justify their approaches within the unrelenting press for student achievement. While many teachers have adopted mobile technologies and innovative applications that motivate their students, they do so without a clear sense that their efforts will lead to increased measures of student achievement. In his volume *Technology and Assessment*, Michael Russell confirmed, "…*standardized tests are often not well aligned with the learning that occurs with computers* (Russell, 2006; p. 185).

That said, it appears that with the adoption of new core standards for learning and the development of more thoughtful assessments, there is some hope on the horizon. The leading options for Common Core assessments are the tests developed by two consortia funded by federal grants: the Partnership for Assessment of Readiness for College and Careers and the SMARTER Balanced Assessment Consortium. These tests, first administered in spring 2015, are sure to be closely scrutinized as potential solutions to our assessment challenges. It is hoped that the new assessments are more in line with international standards that promote deeper learning and higher order thinking, which would then serve as a big boost for teachers who have not fully adopted technology due in part to strong emphasis on assessing discrete skills and covering required curricula. When teachers see that teaching with technology supports student learning and achievement as measured by current assessments, adoption by teachers may very well reach a tipping point. Resolving the tension, however, between the goals of innovative, twenty-first century teaching and learning and the press for assessment and accountability remains a core challenge for educational reformers. Without progress in this area, the potential of technology-based teaching and learning will clearly not be realized on a large scale in US schools.

3.3 Leaders' Roles and Responsibilities

Empirical evidence shows that no matter how much preparation for integrating technology teachers receive, unless they also have the leadership of their administrator, they may be unable to successfully use that technology most effectively. In fact, several studies have suggested that administrative support is the most important factor in technology implementation and that without it other variables will be negatively affected (Ertmer et al., 2002; Gerard, Bowyer, & Linn, 2008; Hilliard & Jackson, 2011).

Being an educational leader in the twenty-first century requires conquering some very challenging tasks. One of the challenges is meeting the needs of today's learners so they have the knowledge and skills to be college and career ready, and hiring and retaining the right people to make this happen. Increasing expectations, implementing evolving standards, and meeting new policies are also part of the ever-changing challenges dotting the educational landscape today. Learning how to meet these challenges is especially difficult when the landscape continues to shift. Part of the challenge for school and district leaders includes learning how to leverage appropriate technologies for communication as well as instructional and administrative purposes most effectively. Another challenge for twenty-first century leaders is managing constant change, and learning that many changes must be addressed nearly simultaneously.

However, most US administration programs do not prepare school leaders to harness digital technologies to promote a twenty-first-century curriculum, and systems are not necessarily in place to support the changes required. Educators are faced with an ever-changing landscape that demands they remain knowledgeable, update their pedagogy to take advantage of new characteristics, and collaborate for improved student outcomes (Ainsa, 2013; Eyyam & Yaratan, 2014; Karchmer, 2001). Fullan and Langworthy (2014) suggest these "new pedagogies… require students not only to create new knowledge, but also to connect it to the world, using the power of digital tools to do things that value in our knowledge-based, technology-driven societies" (p. 1). New conceptions of formal and informal learning, especially in the maker movement (Martin, Bowden, & Merrill, 2014; Martinez & Stager, 2013; Peppler & Bender, 2013), require continuous professional development and revisions of teacher candidate preparation; school leaders must encourage and support these activities. Professional development now takes many forms from traditional workshops to online collaboration (Cifuentes, Maxwell, & Bulu, 2011; Ertmer et al., 2002; Hartsell, Herron, Fang, & Rathod, 2010). In addition, several studies have suggested that administrative support is an important factor in technology implementation and that without it other variables will be negatively affected (Ertmer et al., 2002; Gerard et al., 2008; Hilliard & Jackson, 2011). In the case of ICTs in education, most change efforts have overly emphasized affordances of hardware and software, supported by generic technology training, at the expense of actual implementation in the schools.

As Vanderlinde and van Braak (2013) noted, "Technology planning in schools is a complex and nuanced phenomenon" (p. 17), and it must involve all stakeholders "in the process of technology planning: the schools' technology coordinator, teachers as leaders, the school team, the school leader and the school community. These actors interact formally and informally and, therefore, influence the process of technology planning" (p. 16).

Levin and Schrum studied several award-winning leaders of schools and districts in California, Maryland, Michigan, Minnesota, North Carolina, Virginia, and Washington who successfully used technology as part of their efforts to improve their schools (Levin & Schrum, 2012; Schrum & Levin, 2012). Their research applied theoretical notions of distributed leadership to analyze school leaders, the context of the schools, and myriad groups and individuals within each school and district in an effort to understand ways exemplary leaders organized, implemented, and promoted student achievement, school improvement, technology implementation, and teacher involvement (Mayrowetz, 2008). Distributed leadership assumes "a set of direction-setting and influence practices potentially enacted by people at all levels rather than a set of personal characteristics and attributes located in people at the top" (Leithwood, Jantzi, & McElheron-Hopkins, 2006, p. 20), which is what they found happening in all the award-winning, exemplary schools and districts studied.

Spillane, Halverson, and Diamond (2001) suggested that to understand leadership, it is important to look beyond what one person can do, or knows how to do, but look instead at what each person brings to the task, build on strengths, and collaboratively tackle issues. Their central premise is that school leadership is "understood as a distributed practice, stretched over the school's social and situational contexts" (p. 23). This lens proved to be exceptionally useful in examining ways teachers and other educators can and do contribute to the success of students and schools.

Levin and Schrum also located their work in a systems approach to change, and elucidating how change occurs in an educational organization made up of interacting, interrelated, and interdependent components (Levin & Schrum, 2012; Schrum & Levin, 2012). Their research supports the literature that suggests all components must work together when making changes, if they are to be sustained and embraced by all (Adamy & Heinecke, 2005; Kopcha, 2010; Senge et al., 2000). Further, their research showed that all parts of a system have to be addressed in concert, and adding one component (e.g., technology), or changing one part (such as the curriculum), is not enough to make a difference in the system. Thus, school leaders need to keep in mind vision, curriculum, professional development, resources, technological infrastructure, as well as communicating with the larger community.

Overbay, Mollette, and Vasu (2011) also suggest that school leaders keep several things in mind as they move through the process of a technology planning experience. First, they remind all of us that it is "not about the technology" (p. 56). They state, "The most important lesson we've learned is that technology initiatives are about people" (p. 57). Second, the plan must fit the school or district, not the "ideal" plan someone else may have adopted. Next, they remind us that professional development must be entwined throughout the entire plan. Fourth, they suggest "collaboration has a very real place in schools implementing a technology initiative" (p. 58). Effective school leaders were adept at reconfiguring time to allow educators to spend quality time talking and planning together (Schrum & Levin, 2012). They developed job-embedded Professional Growth Period in which teachers were given two or three periods during the week to follow their personal professional development plan. This is typically accomplished by removing some noninstructional duties from teachers' assignments. Finally, it was noted that leaders found ways to become turnover proof because if they have only focused on a few key individuals, the school may end up without teacher leaders if there is a rapid change in staff.

It seems clear that it is not enough to provide preservice and inservice educators with opportunities to learn with and use technology for teaching and learning; it is essential that the entire system of an educational enterprise be engaged, involved, and supported to truly prepare our learners for their future. Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, and Sendurur (2012) stated that to make a difference in learning, "…technology [must] be placed in the hands of students, who are encouraged and enabled to utilize it in the same ways, and for the same purposes, that professionals do—that is, to communicate, collaborate, and solve problems" (p. 24). Furthermore, these authors found that increasing access was not enough "if this increased access was not accompanied by a corresponding shift in teachers' pedagogical beliefs" (Ertmer et al., 2012, p. 24). Also, it is important to remember that teachers' beliefs and knowledge can be impacted by other factors including "culture, socioeconomic status, and school organizational structures" (Harris & Hofer, 2011, p. 213). For example, if there is not strong support for technology integration by the administration or among the teachers in a school, those wanting to integrate technology may be negatively impacted. Ertmer and Ottenbreit-Leftwich (2010) suggested that encouraging small changes based on the teachers' comfort levels may lead to larger overall changes in the way they approach technology integration.

4 Conclusion

This chapter has highlighted the need for and challenge of preparing our learners for their future; this challenge must be met by preparing current and future teachers and leaders to consider all available resources, pedagogies, and authentic activities in reaching this goal. Institutions that prepare teachers and leaders are obliged to ensure their graduates have knowledge and experience in accomplishing this goal, and further, that professors have the professional development they require to maintain currency. It may no longer be acceptable for primary and secondary schools to be better equipped than colleges of education (Schrum & Levin, 2015).

What will it take for our educational system to move forward? Infrastructure is essential but not sufficient. Regardless of the improvement in the technological infrastructure, it is important to remember regarding the use of ICT that

> While the availability of computers and Internet connections at schools is clearly a prerequisite for ICT use, it is a necessary but not a sufficient condition. The availability of educational software and other digital learning resources and the ICT competences of teachers are equally important in ensuring broader and more efficient use of ICT in the teaching and learning processes in school and at home. (OECD, 2010, p. 171)

Policies and practices must support risk taking, innovation, creativity, and questioning by students as well as by teachers. Professional development must be continuous and relevant to reimagining the educational system as we know it. Student outcomes must be broadened beyond one high stakes test at the conclusion of a year; systematic assessment is necessary to promote learning rather than just rate learning. The global educational community has begun to work together to help identify common needs and challenges; more importantly, it is starting to share research and best practices. Together we can create strong research agenda to improve educational opportunities and outcomes for all our learners.

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Chapter 3
Initiation and Implementation: Changes to Teacher Education in Ireland

Rose Dolan

Abstract Fullan (1991) described the process of change as having four broad phases: initiation, implementation, continuation and outcome. The education system in Ireland has undergone unprecedented change since the Education Act of 1998 and most particularly with the formation of the Teaching Council in 2006. Since 2011, the Council has produced four policy documents, a revised code of conduct and at least three documents relating to procedures and requirements for admission to ITE and registration upon completion of ITE, all relating to the profession of teaching in Ireland. This has resulted in a period of immense change for University education departments and for colleges of education. Much of the change is still situated in the initiation and early implementation phases. This chapter provides a context for those changes, outlines how they came to pass and considers the implications of so much change within a system in a short period of time. It looks at the effects of these changes on those who aspire to be teachers in Ireland in the second decade of the twenty-first century.

Keywords Initial Teacher Education (ITE) • Induction • Policy development • Change

1 Introduction

In 1998, the Education Act passed into Irish law. This was a significant moment in the Irish education system as it was the first education act to be passed since the formation of the Irish Republic. It arose from significant public consultation through the National Education Convention of 1993, following the publication of a Green Paper in 1992, and has provided, for the first time, a statutory framework for the Irish Education system that clarifies the roles and responsibilities of the various

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stakeholders in the system. The consultations also paved the way for the establishment of the Teaching Council in 2006, following the Teaching Council Act of 2001. This is the statutory body responsible for the regulation of the teaching profession and the promotion of professional standards in teaching. Although there have been other pieces of education-related legislation that were enacted around the same time and in the intervening period, I contend that the implementation of these two acts has had the most significant impact on the system, on the lives of principals, teachers and pupils and on those responsible for the education of teachers, namely the colleges of education and the universities. The changes brought about by the two acts, which were implemented initially during the country's economic boom, known as the "Celtic tiger era", and then during a period of extreme austerity within the country, have challenged societal, economic and educational systems within Ireland. They have also brought into question the understanding of the role of education in society and of the competences needed by practitioners within the system.

1.1 Introduction to the Irish Education System

The Irish education system, like many other countries, comprises primary, secondary and tertiary education. The country has a population of approximately 4,609,600 of which 23 % are currently attending some form of educational institution (Central Statistics Office, 2014). There are 3286 primary schools, catering for 536,317 pupils and 723 secondary schools, with a student population of 333,175 (Department of Education and Skills, 2014a, 2014b). As can be seen from these figures, there is a population bulge moving through the system at the moment, resulting in a need for increasing provision of formal education at primary and secondary levels, in the immediate and in the future.

The vast majority of primary and secondary schools are state funded, but many are privately owned. 96 % of primary schools are owned by religious patrons (Coolahan, Hussey, & Kilfeather, 2012) with 52 % as the corresponding percentage for the secondary sector (ESRI, 2013).

Children must attend school between the ages of 6 and 16 but in reality, most children begin school between the ages of four and five. While there is no national provision for pre-schooling in Ireland, the Irish government has invested in some provision outside of the formal education system, through private, voluntary and community interests. In 2011/2012, 97 % of 4-year-olds were enrolled in school, of which 58 % were enrolled in pre-primary education (Department of Education and Skills, 2015).

The majority of teenagers continue to the end of the secondary cycle, which equates to ages 17–18. Latest figures from the Department of Education and Skills (Department of Education and Skills, 2015) show that 90.6 % of the cohort that entered second-level education in 2008 completed the Leaving Certificate examination, a public examination held at the end of the senior cycle of secondary education in Ireland.

The third-level sector has traditionally comprised Ireland's 7 universities, 14 institutes of technology and 7 colleges of education, all substantially funded by the state. There are also a number of independent private colleges in the system and a number of other third-level institutions, providing specialist education in professions such as medicine and law (Department of Education and Science, 2004). In addition, the further education sector offers programmes that are not part of the third-level system but occur after second-level schooling, including programmes such as Post Leaving Certificate courses, second chance education opportunities, adult literacy and evening adult programmes (Department of Education and Science, 2004).

Ireland has participated in the Programme for International Student Assessment (PISA) since its inception in 2000. The most recent PISA results show that Ireland is above the OECD average performance in each of the three domains, with a rank of 7/64 in reading, 20/64 in mathematics and 15/64 in science (Perkins, Shiel, Merriman, Cosgrove, & Moran, 2013). Statistics from the OECD (OECD, 2015) also show that in 2011, Ireland devoted 6.2 % of GDP to public expenditure on education. This spending appears to be mainly in the area of teacher salary. After 15 years of experience, teachers in both primary and secondary sectors can expect to have one of the highest salaries among OECD and partner countries.

The ratio of students to teachers in secondary and tertiary institutions is one of the largest among the OECD and partner countries, with a 19/1 ratio at tertiary and 15/1 at secondary level. Time spent teaching is comparatively large, with primary teachers teaching 915 h per year and 735 h per year for the secondary teacher (OECD, 2015). These figures represent class contact time and do not include the non-instruction time spent by teachers.

1.2 Changes to the System Since 1998: The Establishment of a Teaching Council

In 1998, the Education Act was passed into Irish law, paving the way for a number of changes to the Irish education landscape. Among other things, it clarified the roles and responsibilities of principals, teachers, boards of management, the school inspectorate and the Minister in relation to primary, secondary, adult and continuing education and vocational education and training. Most significantly, it provided a statutory framework for education in Ireland for the first time since the foundation of the state. This act arose from the publication of Green and White Papers and a consultative forum that gave interested citizens the opportunity to contribute to the design of the act.

The publication of the 1992 Green Paper on Education, Education for a Changing World, was a significant moment in Irish education. As the public responded to the invitation to comment on the paper, the significance of education in the lives of Irish citizens became apparent. According to Coolahan, "almost 1,000 written submissions were lodged with the Department of Education in response to the Paper" (Coolahan, 2007, p. 11). The government responded to this interest by setting up a National Education Convention, held in Dublin Castle in the autumn of 1993. Stakeholders in education made submissions to the convention and the subsequent report in January 1994 was highly influential in the construction of the White Paper, Charting our Education Future, published in 1995. One of the most significant actions resulting from the Convention and the White Paper was the decision to set up a Teaching Council, which would "give the teaching profession a degree of control over and responsibility for its own profession" (Coolahan, 1994, p. 90). This Council would replace the Secondary Teachers' Registration Council and would act as the "competent national authority for the implementation of the relevant European Union directive in relation to the mutual recognition of teacher training qualifications" (Department of Education, 1995, p. 135). The Teaching Council Act was signed into law in 2001, and the first Council was established in 2006.

Among the first actions undertaken by the newly established Teaching Council was the publication of a Code of Professional Conduct for Teachers in 2007 and a revised version in 2012. Both included standards relating to Teaching, Knowledge, Skill, Competence and Conduct. The consultation process that accompanied the drawing up of the initial Code took place in a climate where debates about competences and learning outcomes were taking place at both national and international levels.

1.3 Competences and the Role of Learning Outcomes

In 2003, EU member states drew up the "Common European Principles for Teacher Competences and Qualifications". This document highlighted three broad areas of commonality for teachers, namely working with others, with knowledge, technology and information and with and in society (European Commission, 2003, p. 5). An OECD study in 2005 found that there was a general trend "towards changing requirements for teacher certification from input measures (such as number of courses taken or credit points) to output criteria, namely knowledge, skills and competences measured in multiple ways, including portfolios" (OECD, 2005, p. 115).

Although there was a move away from a more behaviourist approach to education internationally, the same could not be said of Irish education, particularly Irish higher education, at the time. As higher education in Ireland worked towards the implementation of the Bologna process at European level and the national qualifications authority (NQAI) framework within the country, this conflict became evident within the system. The ECTS users guide indicated that learning outcomes would be described "in terms of what a student is expected to know, understand and/or be able to demonstrate after completion of a process of learning', the recommended approach in higher education in the Republic is to adopt a behaviourist approach based on Bloom" (Dolan & Gleeson, 2007, pp. 4–5). It is interesting to note that the Code of Professional Conduct (2007; Teaching Council, 2012) have more in common with the OECD and ECTS understanding of learning outcomes than with a more behaviourist approach.

In addition to the Code of Professional Conduct, the first Teaching Council published a number of other policy documents during its term of office. Among these documents were:

- Teaching Council [Registration] Regulations 2009;
- Policy on the Continuum of Teacher Education June 2011;
- Initial Teacher Education: Criteria and Guidelines for Programme Providers August 2011; and
- Initial Teacher Education: Strategy for the Review and Professional Accreditation of Existing Programmes September 2011.

The document relating to Initial Teacher Education criteria contains a number of learning outcome statements for graduates of the programme. These are also in keeping with a more holistic understanding of learning outcomes and are appropriate to induction into the thought process of a discipline, as described by Stenhouse (1975).

1.4 The PISA Effect

As mentioned earlier, Ireland's results in PISA have usually been above the OECD average. In 2009, the PISA results differed from the relatively consistent results of the three previous assessments. The first results from PISA 2009 were published in December 2010 and showed declines in rankings in two of the three domains. While the scores were still above the OECD average in both reading and science, they were below the OECD average in mathematics. Furthermore, the rankings in the three subject domains were as follows: reading 21/65, showing a drop from 5/56 in 2006, mathematics 32/65, a drop from 22/57 with science showing an increase to 20/65 from 20/57 (Perkins, Moran, Cosgrove, & Shiel, 2010; Eivers, Shiel, & Cunningham, 2008). The Department of Education and Skills response to the PISA results clearly indicated that changes were forthcoming, or already in train, to address the decline, particularly in literacy and numeracy. The report states:

> The OECD has noted that 'performance changes [in PISA] are associated with a fairly large standard error'. Irrespective of whether or not the decline in the scores on the PISA test represent a real decline in standards, the Minister for Education and Skills takes these findings seriously and is taking a proactive approach to improving literacy and numeracy standards (Department of Education and Skills, 2010a, 2010b, p. 1).

The report also indicated that a national plan had been launched in November 2010 to address issues of literacy and numeracy and that this plan included radical changes for teacher education. These radical changes included, among other things, an extension to the duration of Initial Teacher Education programmes to 4 years at undergraduate level and 2 years at post-graduate level, effective from 2013 to 2014 for the Primary Teaching qualification and from 2014 to 2015 for the secondary qualification (Department of Education and Skills, 2010a, 2010b). By June 2011, the Teaching Council had published the Criteria and Guidelines for the new ITE programmes (Teaching Council, 2012), and those responsible for the design and delivery of such programmes began the task of programme reconceptualisation and redesign.

1.5 Reconfiguration of Initial Teacher Education

It is worth noting at this point that the announcement of the extension of initial teacher education programmes was made in a highly unusual manner. In 2010, a draft strategy for literacy and numeracy called "Better Literacy and Numeracy for Children and Young People" was published by the Department of Education and Skills (2010a, 2010b). It contained an invitation to engage the Irish public to engage with the strategy and to respond to it. Some of the proposed actions included:

1. Setting new, higher standards for entry into initial teacher education;
2. Review the content and duration of Initial Teacher Education programmes at both primary and secondary levels;
3. Provide support to newly qualified teachers in the areas of literacy and numeracy;
4. Provide continuing professional development opportunities for teachers in literacy, numeracy and assessment.

Responsibility for actions 1 and 2 rested with the Department of Education and Skills, the Teaching Council and the Higher Education Authority in conjunction with the providers of Initial Teacher Education. Target dates of 2012–2013 for the extension of primary ITE and 2013–2014 for secondary ITE were proposed.

In common with the production of the Green Paper on Education in 1992, the invitation to respond was welcomed and 380 interested individuals and organisations responded (see http://www.education.ie/en/Schools-Colleges/Information/Literacy-and-Numeracy/Literacy-and-Numeracy-Submissions/). Organisations such as the teacher unions, Barnardos, library associations and others published their responses, as did statutory bodies such as the National Council for Curriculum and Assessment (NCCA) and the National Council for Special Education (NCSE). Submissions were also received from the providers of Initial Teacher Education within the state.

While all respondents addressed the literacy and numeracy issues, it is unsurprising that the providers of ITE programmes responded most strongly to the proposals about the extension of the ITE programmes. In general, these responses welcome the extension of the ITE programmes. This is also unsurprising as ITE providers had advocated such a change for many years.

The extension to the duration of ITE programmes at primary level had been recommended in the report from the Primary Working Group (Report of the Working Group, 2002a, 2002b) but not in the report on secondary ITE, completed in the same year (Report of the Working Group, 2002a, 2002b). That report, in common with reports from the OECD (OECD, 1991, 2005), opted for developing the induction of newly qualified teachers rather than extending the programmes. Interestingly, the country background report that was prepared for the OECD (Coolahan, 2003) recommended an extension of the ITE programmes coupled with a structured programme of induction for new teachers on entry to the profession.

In its submission about the Literacy and Numeracy strategy, the Forum for Heads of Teacher Education in Ireland (FHTI) noted that the "proposal to increase the duration of concurrent initial primary teacher education programmes to four years, and of consecutive ITE programmes to two years is strongly welcomed. This policy change has been advocated by teacher educators for many years" (Forum for Heads of Teacher Education in Ireland, 2011, p. 1). The unusual manner of the announcement was also noted at a consultation with the ITE post-primary providers in March 2011, where the point was made that it was "strange to find major structural changes in a document on literacy and numeracy, yet there is a welcome for the structural changes proposed" (Department of Education and Skills, 2011a, 2011b, p. 1). Whatever the vehicle for extension of ITE, the programme providers in general welcomed it.

The literacy and numeracy strategy also indicated that changes would be made to the standards for entry into ITE programmes, and this has also commenced. Entry into consecutive secondary teacher education programmes for the academic year 2015 now requires specific modular requirements as part of the undergraduate degrees while work continues on the entry requirements for concurrent degrees.

As ITE providers commenced the work of redesigning their programmes to meet both the requirements of the Teaching Council and the relevant Higher Education Institution (HEI), the Department of Education and Skills commissioned a report on the structure and provision of ITE in Ireland. The impetus for this came from a recognition that there were 19 state funded, and 3 private, providers of ITE offering in excess of 40 ITE programmes. The review comprised an international panel led by Pasi Sahlberg, the Finnish educationalist. The panel met with ITE providers and with relevant personnel from the HEIs and published the results of their review in the summer of 2012. Key recommendations included the reduction of the number of programmes, strategic restructuring of programme providers into six configurations encompassing the full range of sectoral teacher education from early childhood through to adult education (Department of Education and Skills, 2012a, 2012b). In most instances, this required ITE programme providers to plan not only for the design of a new ITE programme but for restructuring of the Department/School of Education. The ambition of the review was that "by 2030 Ireland will have a network of teacher education institutions based on a small number of internationally comparable institutes for teacher education" (Department of Education and Skills, 2012a, 2012b, p. 24) and will offer programmes in both ITE and CPD. At the time of writing, much work has been done to bring together the component parts for these institutes but it is an additional institutional change at a time of already significant change to ITE in Ireland.

1.6 Induction in Ireland: Phase Two of the Continuum

As mentioned earlier, the Teaching Council published a Policy on the Continuum of Teacher Education in June 2011. It outlined the significance of the three I's, namely initial, induction and in-career development, in the working life of the teacher. In addition, the Council adopted another three I's to underpin all stages of the continuum: innovation, integration and improvement (Teaching Council, 2011a, 2011b). The section of the Teaching Council Act relating to induction was commenced on September 1st 2012, and the delivery of the induction programme was undertaken by the National Induction Programme for Teachers (NIPT). Induction programmes for newly qualified teachers had been running in the country since the introduction of a pilot programme in 2002. This programme, the National Induction Pilot Programme for Teachers (NIPPT), had begun in 2002 as a result of a partnership initiative between the Department of Education and Science, the three teacher unions and the ITE providers. At primary level, the programme was housed in St. Patrick's College, Drumcondra, Dublin, one of the primary ITE colleges, while the secondary programme operated from the School of Education in University College Dublin, which was one of the providers of ITE for the secondary system. Both programmes operated independently on the ground within their sectors but had a common national steering committee and common underlying principles. There was a commitment to a whole school approach, to working with School Principals and to training mentors to work with the newly qualified teachers (NQTs). It appears that the initial intention was to complete the pilot programme after 3 years, as evidenced by a comment in 2005 from the then Minister for Education, Mary Hanafin, who commented that she looked forward to considering the final Report of the recently completed National Pilot Project on Induction (Hanafin, 2005); however, the pilot project continued for a further 5 years with funding confirmed on a year-by-year basis.

By September 2010, NIPT was established and responsibility for the delivery of induction workshops was delegated to them. NIPT worked with the Teaching Council in the development of induction in the country, both prior to and subsequent to the commencement of Section 7 (2) (f) and (g) in September 2012.

In January 2012, the Teaching Council consulted stakeholders on its proposed Career Entry Professional Programme (CEPP), but this proposal caused much concern within the education community and was significantly amended as a result of the consultations. A new model was drawn up and in September 2013, after further consultation with stakeholders, the Teaching Council introduced a new model of induction and probation as a pilot programme to run from September 2013 to 2016 (Teaching Council, 2012). This model contains the workshops developed by the NIPT but increases significantly the role of the school in the induction and probation of new members into the profession. The secondary schools became involved but initially the Irish National Teachers Organisation (INTO), the union for primary teachers, instructed its membership not to be involved in the pilot programme. In December 2014, the pilot project has 150 schools and 190 NQTs involved in the project (Teaching Council, 2012).

1.7 *In Career Development: The Third Phase of the Continuum*

The third component of the continuum, continuous professional development for teachers, has now come to the fore. The Teaching Council recently issued an invitation for suggestions about the development of a national framework for CPD in

Ireland (Teaching Council, 2014). This invitation was issued in the first instance to the registered teachers only and took the form of (a) consultation workshops, (b) an online questionnaire for individual teachers and (c) school-based meetings.

This first phase of the consultation was completed on January 16th, 2015. The next phase of the process involves the collation of the feedback with a view to designing the first draft of the framework. This will then go to teachers and to the stakeholders for further consultation before the publication of a CPD framework in March 2016.

The amount of change within the education sphere has been significant since the commencement of the Education Act in 1998. But the changes to the profession of teaching have been even more significant since the first.

Teaching Council came into being in 2006. In the 8 years since its inception, there have been significant changes made in relation to teaching in Ireland. All ITE programmes have now been reviewed, accredited and extended. Induction workshops are now mandatory for all NQTs and, with the commencement of Section 30 of the Teaching Council Act in September 2014, all teachers at primary and secondary levels within the state who are paid from state funds are registered with the Teaching Council. The vast majority of the changes have been brought about through consultation with stakeholders, and the effect of these consultations can be seen in the differences between draft and final versions of many of their policies.

1.8 Curricular Changes and the New Junior Cycle Programme

Concurrent to the implementation of changes to the structure of the teaching profession in Ireland was another change, namely a change to the Junior Cycle Programme in secondary schools. In November 2011, the National Council for Curriculum and Assessment (NCCA), a statutory body responsible for advising the Minister, published a framework for Junior Cycle, including a change to the assessment processes currently used as part of the Junior Cycle. The document, "Towards a Framework for Junior Cycle—Innovation and Identity", was developed in consultation with stakeholders in the system and clearly indicated that changes to all other parts of the programme was dependent on a change to the mode of assessment, particularly the reliance on a state-administered terminal examination (NCCA, 2011). In 2012, the Minister for Education and Skills, Ruairi Quinn, announced the radical reform of the Junior Cycle with the changes to be introduced to students on an incremental basis from September 2014 (Department of Education and Skills, 2012a, 2012b).

Although this chapter has not taken curricular change within the schools as a focus, this change is particularly significant in Irish education. It occurs in a climate of austerity, where posts of responsibility were cut within schools and teacher salaries were reduced as part of a national plan. Not only does it affect the tradition of a state examination at the end of the Junior Cycle of education, its introduction coincided with the introduction of the extended ITE programmes at second level and with the development of the pilot programme for induction. The Junior Cycle changes were, and still are, highly contested. To date, two strike days have been called by the teacher unions and attempts at mediation between the Department of Education and Skills and the teacher unions are at a standstill. In the current climate of austerity within Ireland, the number of changes appears to have been too much for the teaching population to contend with. Yet the irony is that in many schools, the developmental work continues. Pilot schools for the Induction programme continue their work, experienced teachers engage in the development of student teachers, work goes on in relation to developing assessment for and of learning within schools and classrooms. While the national picture is one of unrest, not just in the education sphere but in other areas of life as well, there also appears to be a sense of "getting on with it" in many aspects of working life.

2 Challenges and Opportunities for Educationalists

Fullan (1991) described the change process as having four broad phases: initiation, implementation, continuation and outcome. While changes do not occur in a linear fashion, with one change completed and institutionalised before the next change is initiated, it is worth considering the changes within Irish education at the moment and the phase within which each finds itself at this moment in time.

Changes to ITE programmes and to the institutional structures supporting them lie somewhere between initiation and implementation as does the new process of induction of newly qualified teachers. CPD is at a pre-initiation stage, with consultation as part of the initiation process. Junior cycle changes are stalled somewhere between initiation and implementation. This points to a system that is heavily loaded at the initiation and implementation stages, where a number of the changes are both strongly interlinked and dependent on the same group of educators to implement the changes. Yet it is natural that these changes, particularly to the profession, would occur synchronously. As the requirements for entry to programmes change, the programmes are longer and more costly, and the exit award is at the master's level for consecutive programmes, it is understandable that the induction into the profession is also experienced in a structured and professional manner. Teachers who now take a role in induction into the profession also need opportunities to upskill and to have their professional development recognised in a formal manner. It gives a real opportunity for the profession to take upon itself a responsibility for who enters the profession and to have a clear part to play in that decision. As student teachers spend more time in schools, it gives experienced teachers a real opportunity to involve themselves in educating the profession and to become teacher educators in the first-order setting of the school.

With every opportunity comes a challenge or a constraint. In this instance, the biggest concern with the change to ITE lies in the areas of equality and diversity. While the Finnish model of extended ITE programmes at the master's level is lauded, one must also look at the ways in which this model is funded. Those who choose to become teachers will have fees paid and will receive a stipend while they study. For me, this is an important part of the pre-service induction into the profession as it allows those who will enter the profession to do so in a focused manner from the very beginning. In Ireland, the concurrent programmes currently have total fees of €10,800–€12,000 across the 2 years. Due to public funding of the fees for undergraduate programmes, students on concurrent programmes incur much smaller costs. The change in policy could potentially result in concurrent programme teacher education becoming the programme of choice for the potential teacher. This financial burden will also affect those who decide to enter teaching as a second career as they typically have other financial commitments, such as mortgages and families, at that stage of their lives. When the Education Department of NUI Maynooth responded to the Literacy and Numeracy Strategy, one of the points made concerned the potential reduction in diversity within the teaching population.

As teacher education courses are extended to 2 years duration, the cost to student teachers, in terms of fees, and in lost earnings, are increased. It would be regrettable if, as a consequence, teaching became less accessible to those from less wealthy families. Care should be taken to ensure that the extended duration of the programmes is matched by the availability of grants and other supports to ensure equitable access to the profession from a diversity of backgrounds (Education Department NUI Maynooth, 2011, p. 4).

Although grants such as the Back to Education grant and Student Universal Support Ireland are available, early indications from the first student cohort on the 2-year programmes points to the awarding of very small grants that in most instances cover only 30 % of fees. Graduates face the prospect of beginning their work as teachers with substantial debt accrued, a reduced starting salary and a lack of full time teaching jobs available.

Another area of concern lies with the current induction model involving attendance at a prescribed number of workshops over the course of the year. In the absence of employment opportunities for NQTs, some find themselves attending the workshops while unemployed, others while teaching on temporary/part-time contracts with little consistency and a third group who have emigrated but return to attend these workshops as part of their requirement for registration. Some induction models, such as that used in the Scottish system, offer an induction year where the NQT is placed with a particular school, is given a timetable amounting to 70 % of a full teaching timetable and is offered support both at school and at national level. The introduction of such a strategy would serve two purposes; it would allow the NQT to consolidate what he or she has learned in ITE, and it would ensure that there is an income for the first year which could be used to alleviate some of the debt accrued during the ITE programme.

3 Thinking About the Future

As mentioned earlier, we are at initiation and implementation stages of the change process in many structures within the education system in Ireland. Where will these changes be in 5 years or in 10 years time? Will we be at the continuation stage, where the changes have become institutionalised and the twin processes of initiation and implementation are distant memories? What needs to happen over the next 5 years in order for the changes to become institutionalised?

Some of the factors have already been mentioned in the previous section. There is a need to think systematically about the impact of the changes on the system and the individuals therein. Structured funding opportunities are necessary, as are structures that support the NQT in finding teaching work in the years post-qualification.

As the economic future begins to brighten, the lessons we learned in the aftermath of the Celtic tiger need to be taken on board. A significant percentage of GDP needs to be earmarked for education. Meaningful career development prospects need to be developed for the teaching profession. We need to find ways to learn from our returning emigrants and the things that they have learned while teaching in other countries and other systems. Above all, we need to remember that the use of consultative processes in the design of policy is critical to the continued democratic development of education in Ireland.

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Chapter 4
Digital Learners and Digital Teachers: Challenges, Changes, and Competencies

Ronghuai Huang and Junfeng Yang

Abstract Technology has changed almost every sector of society, but there are little changes in education compared with changes in the other sectors. In the past, research mainly focused on using technology to improve learning performance or teaching efficiency. However, little attention has been paid to the influence of technology on the characters of students and teachers themselves. Students and teachers are the two most important factors in any educational system. In this age of transformations, attention should be paid to the changes in students and the knowledge of teachers. In this chapter, we first discuss the character of students who have grown up with digital technologies and the Internet. Then, we analyze the changes in teachers' knowledge, and what knowledge needs to be developed. Finally, we analyze the challenges, changes, and the competences for students and teachers in this digital age from the perspective of an educational ecosystem.

Keywords Digital learners • Digital natives • Digital teachers • Net generation • PCK • TPCK

1 Introduction

With the rapid development of information and communications technologies (ICT), technology has gradually seeped into all sectors of society, and all walks of life have experienced changes due to technology. The introduction of multimedia technology in education has the potential to change the process of learning and teaching. Current research has focused mainly on the impact of technology on

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learning performances or teaching efficiency. Little attention has been paid to the deep changes in students and teachers as a result of new technologies. From an educational ecological standpoint, these changes may be an important barrier to educational reform. With the application and popularization of technology in all walks of life, learning environments have changed, the characteristics of the students have changed, and the abilities of teachers have also changed. It is generally believed that students, teachers, and content are the three basic elements of an educational system, with students and teachers being the most dynamic and important factors. Today, the three elements themselves have undergone significant changes, and reexamining the special characteristics of these three elements in the digital age have, and will enable us to more clearly understand the educational process to promote educational reform.

2 Digital Generation of Learners

Because students' lives today are saturated with digital media at a time when their brains are still developing, several popular press authors have suggested that media use has profoundly affected students' abilities, preferences, and attitudes about learning (Thompson, 2013). Tapscott (1998), Howe and Strauss (2000), Prensky (2001) and Gasser and Palfrey (2009) have argued that today's generation of learners behave differently than the previous generation because they have been immersed in a world infused with digital technologies. It is claimed that they learn differently, they exhibit different social characteristics and have different expectations about life and learning. These researchers believe that this digital generation of learners prefers active rather than passive learning, using digital technologies and collaborating to finish work. However, researchers like Bennett, Maton, and Kervin (2008), Selwyn (2009), Chris Jones, Ramanau, Cross, and Healing (2010) and Romero, Guitert, Sangrà, and Bullen (2013) have argued that although digital technologies are associated with significant changes in the lives of young people, there is no evidence of a serious break between young people and the rest of society with regard to learning.

The debate started by Bennett et al. (2008) continues drawing attention from many researchers even now (Bennett & Maton, 2010; Demirbilek, 2014; Jones & Czerniewicz, 2010). The current debate about *digital natives* could be interpreted in two ways. The first way concerns whether to admit there is a generation of digital learners entering schools, with different behavioral characteristics and learning preferences from the previous generation of learners; authors such as Prensky (2008) and Wilson (2010) believe that digital natives have been entering school, and their behavior and thinking habits are quite different from their parents who might be considered *digital immigrants*. Researchers such as Bennett et al. (2008) and Chris Jones (2013) believe that students vary widely in gender, socioeconomic backgrounds, countries, and regions considering technology use and learning preferences.

The second way to think about this concerns whether taking age as the main mechanism to divide digital natives from digital immigrants is meaningful. Tapscott (1998) argued that the *net generation* was born between January 1977 and December 1997. On the other hand, Prensky (2001) took the 1980s as a dividing line; people born before 1980 are regarded as digital immigrants and after as digital natives. Authors such as Bennett and Maton (2010) believe that taking age as a division mark is too arbitrary and prone to cause confusion and misunderstanding, in part because digital immigrants can never become digital natives with the implication that a teacher born before 1980 might never be able to meet the needs of digital native students.

The debate sketched above with seemingly contradictory views is in fact only two perspectives of many to describe the situation. These two include a macro-perspective focused on a general tendency, and a micro-perspective focused on specific characteristics and learners. Both the macro- and micro-perspective are critical for understanding the new generation of learners. Q. Wang, Myers, and Sundaram (2013) suggest that there is a continuum rather than a rigid dichotomy between digital natives and digital immigrants, which can be conceptualized in terms of digital fluency. Accordingly, we propose the neutral term "digital learner" to reconcile the above debate. Age is not the definitive division marker of a digital learner; the time spent using digital technologies and the technologies used are better indicators of a digital learner, which we hope to establish in this chapter.

Some researchers argue based on empirical research about the impact of technology on today's learners (Bennett & Maton, 2010; Gros, Garcia, & Escofet, 2012; Thomas, 2011). A growing body of theoretical and empirical research aims to identify characteristics of young people's experiences with technology and the factors influenced their habits in using ICT (Corrin, Bennett, & Lockyer, 2013; Demirbilek, 2014; Romero et al., 2013; Varela-Candamio, Novo-Corti, & Barreiro-Gen, 2014). Howe and Strauss (2000) identify these basic characteristics of millennials (born between 1980 and 2000): (a) feeling special, (b) having been sheltered, (c) being confident, (d) being team-oriented, (e) being achievement-oriented, (f) feeling pressured, and (g) being conventional. Prensky (2001) argues that twitch-speed, multitasking, random-access, graphics-first, active, connected, fun, fantasy, and such are the major characteristics of digital natives. Oblinger (2003) believes that high digital aptitude, a preference for multitasking, literacy across multiple media, a culture for sharing information, a need for speed of information delivery, and a desire to be constantly connected were the characters of the new students entering into university. Teo (2013) developed a digital natives assessment scale with the four characteristics: (a) grew up with technology, (b) is comfortable with multitasking, (c) is reliant on graphics for communication, and (d) thrives on instant gratification and rewards. Teamwork or collaboration is another unique and important character (Tapscott, 2008).

As a consequence of this review of the literature, the following characteristics are those that should be empirically tested in further research: (a) grew up with technology, (b) likes to multitask, (c) enjoys teamwork, and (d) is reliant on graphics (see Table 4.1).

Table 4.1 Characteristics of digital learners

Dimensions	Details
Grew up with technology	– How many years he/she has used the Internet
	– Time spent on the Internet every day
	– Self-confidence in using the Internet
	– Using digital devices
Likes multitasking	– Prefers to listen to music while doing homework, etc.
	– Is able to chat with classmates while doing homework, etc.
	– Always uses more than one computer application
	– Uses multiple resources for acquiring knowledge after class
Enjoys teamwork	– Collaboration online/Collaborative learning in classroom
	– Curiosity about new events online
	– Chatting and meeting online
	– Sharing with others online
Is reliant on graphics	– Watches video online/offline
	– Prefers to read graphics than texts
	– Prefers to use pictures to express

3 Teachers' Knowledge: From PCK to TPCK

With the times changing and technologies utilization in education expanding, the scope and the nature of teachers' professional knowledge has changed. In order to promote teachers' professional development, it is particularly urgent to sort out teachers' professional knowledge and to understand the characteristics of the contemporary teachers' knowledge from an historical perspective. Pedagogy Content Knowledge (PCK; Shulman, 1986) as a framework for teachers' knowledge has been taken as an important reference for teachers' professional development and pre-service teachers' training from the 1980s to the present. In today's information society, digital technologies have swept through every corner of life, and it also has increasingly affected what teachers should know and be able to do. Technology Pedagogy Content Knowledge (TPCK; Mishra & Koehler, 2006) emphasizes the interaction of technology in every element of PCK, along with the integration of technology into the entire process of teachers' professional knowledge, which is now generally taken as a framework for teachers' knowledge in the information age. Understanding the changes from PCK to TPCK is at the core of promoting education reform.

3.1 PCK and Teachers' Knowledge

In the early 1960s and 1970s, with the influence of behaviorism theory, the study of teachers' knowledge mainly focused on the effectiveness of teaching by investigating teaching behaviors associated with student achievement, demonstrating that some of teaching behaviors could promote student achievement (e.g., providing timely and informative feedback after each student performance). With the rise of cognitive psychology, educational studies began to shift to the cognitive processes behind teaching and learning behaviors, with a focus on instructional design and the selection of teaching strategies in the classroom. Teaching knowledge was mainly referred to as pedagogy, and a sharp separation between content knowledge and pedagogy developed. In order to resolve this sharp separation, Shulman (1986) proposed a new perspective on teachers' knowledge, which is the PCK framework. He argued that teachers' knowledge should include subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. PCK not only emphasized the subject matter content knowledge and pedagogical knowledge, but it also emphasized how to integrate the two knowledge areas effectively in different educational contexts.

PCK was a major development in teachers' knowledge, which showed the elements of teachers' knowledge and the dynamic link of the knowledge. PCK provided a theoretical guidance for pre-service teachers' training and teachers' development, emphasizing the integration of subject knowledge and pedagogy, which has boosted the practice of effective teaching.

3.2 TPCK and Teachers' Knowledge

PCK was proposed based on fragmented view of subject knowledge and pedagogical knowledge for teachers' knowledge in the 1980s; it aroused heated debates but was gradually recognized and has been widely used. In the beginning of the twenty-first century, with information technology becoming popular in education, it was urgent for school teachers to improve their ability of integrating technology into education. Many countries carried out countrywide large-scale training to improve teachers' knowledge in using technology. However, the results of the training did not bring the expected improvements in teaching, and many teachers could not well integrate technology into the curriculum to promote effective teaching. Considering the problem, Mishra and Koehler (2006) proposed a conceptual framework by building on Shulman's formulation of pedagogical content knowledge and extended it to include integrating technology into learning and instruction, which they named TPCK. TPCK highlights the connections and interactions among content, pedagogy, and technology. Furthermore, the complex interactions among the three kinds of knowledge was reframed as Technological Pedagogical And Content Knowledge (TPACK) describing it as the total package required for integrating technology, pedagogy, and content knowledge in the design of curriculum and instruction (Jang & Chen, 2010).

TPCK enriched and developed the structure of teachers' knowledge in the information age. TPCK is highly scenario dependent, which could not be isolated from the specific teaching scenarios. Therefore, teachers' TPCK could only be developed in specific teaching scenarios rather than technology training courses.

3.3 TPCK for Chinese Teachers

Teachers' knowledge has changed from PCK to TPCK, and it is easy to see the importance of interactions between technology and other elements of teachers' knowledge in the TPCK. The Chinese government has recognized that teachers' ICT ability is an essential professional factor in the information society. In order to improve their ICT ability, the Chinese Ministry of Education (MOE) has implemented large-scale primary and secondary teacher training regularly, which aims at helping teachers use ICT effectively and updating their teaching philosophies.

The MOE issued the *Educational Technology Competency Standards for Teachers* (*Trial*) *in 2004*, which defines the educational technology competency standards of teaching, management, and technical staff. The MOE launched the *National Primary and Secondary Teachers Educational Technology Capacity Building* program in 2005. More than six million teachers were trained. In October 2013, the MOE launched the *National Primary and Secondary School Teachers ICT Application Capacity Improvemen*t project, combining training, assessment, and application that focus on teachers' active usage of ICT in daily teaching activities. The project stipulated the standards of teachers' ICT capacities, the standards of training courses, and the guidelines for capacity evaluation; the mechanism for this project was based on training by demand, credit management, and self-regulated learning; the training model was blended, situational experiencing and real-time monitoring. The aim of the project was to train more than ten million primary and secondary teachers by 2017. The National Teacher Education Alliance (NTEA, http://www.tuchina.cn) is an innovation project on teachers' education, supported by MOE and jointly sponsored by more than 10 well-known domestic normal universities and research institutions. It is conducted to integrate quality-learning resources depending on online support platform for the change of teachers' education pattern and for the cultivation of qualified teachers in this information age.

4 Challenges, Changes, and Competences

The use of ICT in education is an important element in many countries' educational development strategy because ICT is often anecdotally associated with improvements in quality of classroom instruction, provision of innovative instructional opportunities by teachers for students, and improvements of the capacity at the administrative or policy level (Tolani-Brown, McCormac, & Zimmermann, 2011). Many countries have initiated policies and strategies for the infusion of ICT into their schools, and they share the belief that a critical factor in the nation's economic success is how well their citizens can adapt and thrive in a global ICT environment (Looi & Hung, 2005). Therefore, scaling up the ICT-driven innovation is commonly believed to be a key factor in the further development of education; however, it is also a big challenge for every country.

In this chapter, we held the idea that students and teachers has changed, and educational transformation through using ICT should understand the characters of digital learners and improve teachers' TPCK knowledge.

In order to understand digital learners, research could be carried out in a number of ways:

1. From the perspective of learning psychology to explore whether the students' cognitive style has changed. Cognitive style is the demonstrated habituation behavior patterns of any individual in the cognitive process, which often refers to the consistent individual different preferences of organizing and processing information and experiences. Whether digital learner's information processing model has uniform characteristics by long-term use of digital technology, needs research and confirmation from experimental studies.
2. From the perspective of the neurobiology to explore whether digital learner's brain structure and ways of thinking has changed. Neurological studies have shown that brain structure is evolving constantly, and the brain networks of different learning styles are often different. Whether digital learners have formed unique neural network structure because of the impact of digital technology, requires further study.
3. From the perspective of social psychology to explore whether digital learners have developed a hypermedia thinking because of growing up in the digital environments. In film editing, nonlinear editing for digital video signals are the digital features that make hypermedia possible and widely used. Whether the thinking patterns have changed because of long-term immersion in the digital and network environment, needs to be studied and confirmed from the perspective of experimental psychology.
4. From the perspective of Internet addiction to explore whether the use of technology has generated excessive reliance on technology and what are the undesirable results. All parents have the same confusion of how to guide their children's use of computers and the Internet to avoid excessive use of the Internet. How to confirm the technological dependence and their consequences, so as to clarify the use of technology to provide a reference for parents and educators, will be another important research direction.

In order to improve teachers' TPCK knowledge, research or practice should be carried out in the following aspects.

1. Promote teachers' knowledge transiting from PCK to TPCK. Due to technology integration into teaching, the content of learning has changed, the ways of teaching and learning has changed and the framework of teachers' professional knowledge has changed. Research or practice should be implemented to let teachers realize the change and find ways to develop skills of integrating ICT in teaching. However, when emphasizing the importance of technology, we should avoid the errors of techno-centrism, but to pay attention to the integration of technical and professional knowledge.
2. Development of teachers' TPCK knowledge could not just rely on training, and more authentic training scenarios could happen in real classroom. Classroom teaching is a complex field full of ill-structured problems, where teachers always need to think about a series of problems, like "what to teach," "for whom," "how to teach," "why teach," and so on. The situation in ICT supported classroom teaching will face more ill-structured problems, where training will have the best results.
3. Leveraging technology to boost teachers' professional development. Technologies have enabled innovative patterns of teaching and learning models, such as flipped classroom, micro-course, and MOOCs. The teachers who are confident with using technology always adopt these new emerging teaching and learning patterns to make their classroom success.

Students and teachers are the two most important factors in any educational system. In this information age, digital learners and digital teachers have new characteristics involving the use and integration of technology into learning and instruction. This chapter only raises issues related to these changing characteristics; specifically, the argument is that teacher training and professional development should embrace TPACK. More research is needed to fully understand how best to support the development of teachers' TPACK and what the consequences of doing so will be.

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Chapter 5
Pre-Service Teachers' Perceptions of School Development

Nicole Bellin-Mularski, Dana-Kristin Mah, and Dirk Ifenthaler

Abstract An in-depth understanding of the complexity of factors influencing school organization and development is a prerequisite for successfully responding to constant change within schools, where teachers are expected to play an integral part. This study investigates pre-service teachers' understanding of relevant fields of school development. A sample of 951 pre-service teachers participated in this study. Findings indicate that pre-service teachers' understanding is rather low. Even a 6-month school-based training program does not provide a deeper understanding of factors influencing school development. A competency-based training program focusing on school development is suggested.

Keywords School development • Pre-service teacher • Teacher training

1 Introduction

Over the past years, several large-scale innovations have taken place in the German education system (e.g., the establishment of all-day schools, the restructuring of the first years of preschool, and the modification of the segmented secondary education system with a more comprehensive system). These innovations not only aimed to change the structure of the educational system to ensure more educational justice but also required new educational curricula and cooperation between different professions (Kuhlee, 2015). Researchers have claimed that such organizational change

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is most effective when it is not carried out *top-down*, and educational governance research emphasizes the complex interaction between government, school boards, and actors at the school level when implementing these reforms (Hallinger & Heck, 2010; Harris, 2004). Therefore, teachers are expected to play an integral part in this process of organizational change by developing new forms of cooperation, implementing new learning and teaching methods, and participating in continuing education. Accordingly, coping professionally with school innovations has become an ongoing requirement for teachers (Hsiao, Chang, & Chen, 2013).

Consequently, the standards for teacher education in Germany describe the competence for *innovation and school development* as one of four principles in pre-service teacher education, complementing teaching, educating, and diagnostics (KMK, 2004). The standards of the Standing Conference of the Ministers of Education and Cultural Affairs describe the focus on innovation for pre-service teacher training as knowledge of the aims and methods of school organization and development or knowledge about conditions of cooperation (KMK, 2014). For the present study, we conceptualize school development in a broader perspective as a systematic and reflective process that aims on improving the educational quality at the system, school, and teaching levels.

Educational research distinguishes teacher knowledge in terms of three different fields that have been discussed extensively in the literature. According to Shulman (1986), these are content knowledge, pedagogical content knowledge, and generic pedagogical content knowledge. This theoretical construct has been further complemented by the addition of components such as organizational knowledge and counseling knowledge (Baumert & Kunter, 2006). From a theoretical perspective, knowledge and understanding of school organization and development can be subsumed under generic pedagogical content knowledge. So far, there is relatively little empirical evidence regarding the effects of these different areas of teacher knowledge on educational quality or on student outcomes (Baumert & Kunter, 2006; Darling-Hammond, 2000; Shulman, 1986).

Considering the necessity to actively participate in teaching and school development processes, this study explores the organizational understanding of pre-service teachers. It investigates how pre-service teachers assess their understanding of school development and it explores whether pre-service teachers gain more insight into relevant areas of school development after completing their school-based training.

2 Theoretical Framework

2.1 Teacher Knowledge

Research on teacher competencies identifies a variety of professional competencies teachers need in order to act in and assess complex pedagogical situations. There are different classifications that cover subject, methodological, social, and individual competencies or describe essential competencies and practices that teachers need to acquire (KMK, 2004; Terhart, 2002). Since the 1980s, psychological research on professional competencies and teaching expertise has emphasized the cognitive facet of teacher knowledge. In Shulman's (1987) theoretical framework, teacher knowledge encompasses content knowledge of the subject itself, pedagogical content knowledge about how to present particular problems and topics to students and how to adapt them to learners with diverse interests and abilities, and general pedagogical knowledge, which includes aspects like classroom management, curriculum knowledge, and knowledge of educational contexts. Baumert and Kunter (2006) added organizational knowledge and counseling knowledge to these domains. Within this research, the difference between declarative and procedural knowledge is generally accepted and is further differentiated according to types and qualities of knowledge (de Jong & Ferguson-Hessler, 1996). Declarative knowledge refers to factual knowledge and is a prerequisite for procedural knowledge. Teachers acquire procedural knowledge mainly in the professional phase of their education and during their whole professional career.

Current research focuses on multidimensional aspects of teaching competence. Besides general pedagogical knowledge, pedagogical content knowledge, and content knowledge, it also includes motivational aspects, beliefs, and self-regulation skills (Baumert et al., 2010) or an examination of what distinguishes experienced teachers from novice teachers (Bromme & Haag, 2004). Another focus lies on mathematical content knowledge of teachers and its effects on student outcomes (Hill, Rowan, & Loewenberg Ball, 2005; König & Blömeke, 2009; Krauss, Baumert, & Blum, 2008). Further research focuses on teachers' ability to design lessons and how their cognitive structure (Borko & Putnam, 1996), creativity (Hanke, Ifenthaler, & Seel, 2011; Sternberg & Lubart, 1999), beliefs (Maggioni & Parkinson, 2008), and motives (Watt & Richardson, 2007) influence their lesson planning. In contrast, research on the assessment of general pedagogical knowledge is rare. TEDS-M, a study that examines general pedagogical content knowledge of pre-service teachers at the end of their university education, emphasizes teaching, classroom management, differentiation, and motivation of students as relevant areas (König, 2010).

In a recent research review and conceptual analysis, Cochran-Smith et al. (2012) identified six distinguishable genres that examine connections between teachers' education and outcomes. As genre four, they identified research on teacher preparation programs and their graduates. Studies in this genre focus on graduates of particular teacher preparation programs and outcomes like career paths, beliefs, practices, and sense of preparedness. For the present study, this genre provides insights into research conducted in the field of pre-service teachers and curriculum content (Athanases & Martin, 2006; Fry, 2007; Merino & Holmes, 2006). A majority of the studies examine aspects related to teaching. However, studies researching educational standards and knowledge on school development of pre-service teachers are rare (Blömeke, Felbrich, Müller, Kaiser, & Lehmann, 2008; Houston, 1990; Schaefers, 2002). For example, Cobb (2001) investigated graduates from a professional development school program, showing that these graduates perceive themselves as change agents in schools. Although there is evidence that the program relates to teachers' practices, the sample size is too small to generalize these findings (Cobb, 2001).

It is further argued that a conceptual model for research in teacher education needs to consider a micro-, meso-, and macro-level with corresponding variables (Blömeke et al., 2008; Diez, 2010). This research model suggests that areas of professional competence and individual, institutional, as well as systemic factors influence the achievement of competence during teacher education. Standards of teacher education and competence models are fundamental for reforming teacher education (Cochran-Smith & Zeichner, 2005; Darling-Hammond & Bransford, 2005). For a German discussion, see, for example, Baumert and Kunter (2006) and Terhart (2002, 2012). While current empirical research focuses on the relationship of content knowledge, pedagogical competence, and effects of teacher performance on learning outcomes of students, there is still very little evidence about the organizational content knowledge of pre-service teachers (Kennedy, Ahn, & Choi, 2008). Research indicates that knowledge on school development during pre-service teacher education needs to be linked to existing school development projects to become effective. Additionally, Terhart (2012) states that standards for teacher education are rarely implemented in German higher education and only a small part of the teacher education curriculum focuses on general pedagogical content knowledge as well as school development.

2.2 School Development

In the past decades, reforms in the educational system in Germany have aimed at giving schools more autonomy, for example, decisions regarding the allocation of budgets within the schools, and at the same time schools have become more accountable to students and parents for their outcomes. The theoretical discourse focuses on the school level as the center of school development. This perspective has recently been expanded and now considers conditions and regulations on all levels of the educational systems as important factors for assisting and evaluating school development processes. This complex interaction between the system and the school may result in different governance models (Rolff, 1998). Therefore, theoretical assumptions of school development refer to a variety of theories and emphasize the multilevel character of school development (Maag Merki, 2008). On the governmental and school board level, the general structure and conditions for school development are defined by laws and provisions. The second level encompasses networks of schools and other relevant stakeholders that are involved in school development within the school. The third level represents the actions of the involved persons (e.g., teachers, school leaders) when implementing school developmental processes.

Therefore, school development can be defined as a conscious and systematic transformation that is carried out by the stakeholders at the school level. These activities may focus on three dimensions: teaching (e.g., methodical training, student learning, differentiation), staff development (e.g., supervision, team observation, mentoring), and organizational development (e.g., school management, school concepts, cooperation) (Rolff, 1995). The objective of school development processes is linked to dimensions of school effectiveness research (Creemers, Scheerens, & Reynolds, 2000; Holtappels & Voss, 2008; Scheerens & Bosker, 1997). These models refer to context, input, process, and output dimensions of effective schools and define school development as an important factor for enhancing school quality in these areas (Holtappels & Voss, 2008).

It is generally accepted that schools are embedded in a multilayered organizational system consisting of the general educational context (e.g., a country or state's specific administration and curriculum), school-related (internal) organizational aspects (e.g., school management, innovation), and classroom management. The last of these aspects is considered the most relevant for pre-service teachers (Latz, 1992; Slider, Noell, & Williams, 2006; Stephenson & O'Neill, 2012; van Tartwijka, den Brok, Veldmana, & Wubbels, 2009; Woodcock & Reupert, 2010). However, as mentioned above, competencies focusing on school development are becoming more and more important. For the present study, we conceptualize school development in a broader perspective as a systematic and reflective process that aims at improving the educational quality at the system, school, and teaching levels. As an initial means of accessing the field, we asked pre-service teachers to self-rate their understanding of school development. Thus, the study's objective is to investigate the participants' subjective understanding but not their knowledge or even competencies.

2.3 Research Questions and Hypotheses

This study focuses on the dimension of school development by exploring how pre-service teachers assess their understanding in relevant fields and whether there are differences among pre-service teachers who have completed their school-based training. In particular, it addresses the following research questions and hypotheses:

- How do pre-service teachers assess their understanding of school development? An in-depth understanding of the complexity and interrelatedness of factors influencing school development is a prerequisite for successfully adapting and responding to constant change within schools. Given the inadequately represented curricular elements focusing on school development (Terhart, 2012), we assume that pre-service teachers lack substantial understanding of school development (Hypothesis 1a). In addition, the higher relevance of curricular elements focusing on classroom management in pre-service teacher education suggests a lower understanding of school development (Hypothesis 1b).
- Do pre-service teachers who have completed their school-based training assess their understanding differently? While participating in school-based training programs, pre-service teachers are expected to gain professional experience with regard to school development (Le Cornu & Ewing, 2008). We assume that pre-service teachers who have completed their school-based training have a higher understanding of school development than pre-service teachers without professional experience (Hypothesis 2).

- Do pre-service teachers have appropriate expertise and understanding of the complexities of a school? School development takes place at different educational levels and is a complex interaction between various stakeholders within the educational system (Maag Merki, 2008). Research shows that school development is not fully considered by the curriculum of many universities (Hohenstein, Zimmermann, Kleickmann, Köller, & Möller, 2014). Thus, we assume that pre-service teachers lack expertise and understanding of the interrelatedness and conditions of cooperation to classify the levels adequately (Hypothesis 3).
- Do pre-service teachers with and without school-based training assess the strength of relationships between educational levels with regard to school development differently (Hascher, 2012)? We assume that pre-service teachers who have completed their school-based training will have gained more insight into relevant areas of school development than pre-service teachers without professional experience (Hypothesis 4).

3 Method

3.1 Setting

Teacher education in Germany is divided into teacher education for primary schools and secondary schools. These types differ between the 16 German states regarding the content of educational training and duration. Teacher education in Germany starts with university training of 3–5 years and a practical training phase of between 1 and 2 years and ends with a master's degree. A master's exam is required. An analysis of different curricula of higher teacher education revealed that aspects of school development (e.g., organizational development, classroom management, cooperation) are not consistently implemented in all states (see Table 5.1).

This finding corresponds to an analysis of course regulations and module handbooks for teacher training programs at 16 German universities (Hohenstein et al., 2014). Although goals of school development are implemented at 14 universities, the authors state that it is not clear to what extent the content is covered (e.g., obligatory or not) and that the documents give only a vague description of the content covered.

With the implementation of a new modularized curriculum which also accounts for school development content for teacher education at a German university, pre-service teachers were required to study (1) two scientific subjects (e.g., a combination of biology, chemistry, mathematics, languages, sports) and (2) psychological and pedagogical subjects related to schooling as well as (3) participate in a 6-month school-based training program.

As part of the quality assurance cycle of the newly implemented curriculum, we evaluated pre-service teachers' beliefs, understanding, and expectations. Pre-service teachers were randomly asked to participate in the study. They were asked to complete paper-based questionnaires.

Table 5.1 School development as part of the pre-service teacher curriculum

	Bachelor	Master	Required Course
BW[a]	–	–	–
BY[a]	–	–	–
BE	+	–	+
BB	+	–	+
HB	–	+	+
HH	–	–	–
HE[a]	+	+	+
MV[a]	+	+	+
NI	+	+	+
NW	–	+	–
RP	–	+	+
SL[a]	+	+	+
SN[a]	+	+	+
ST[a]	+	+	+
SH	–	–	–
TH[a]	+	+	+

Note: *BW* Baden-Württemberg (Ruprecht-Karls-Universität), *BY* Bavaria (Ludwig-Maximilians-Universität München), *BE* Berlin (Freie Universität Berlin), *BB* Brandenburg (Universität Potsdam), *HB* Bremen (Universität Bremen), *HH* Hamburg (Universität Hamburg), *HE* Hesse (Universität Kassel), *MV* Mecklenburg-Western Pomerania (Universität Rostock), *NI* Lower Saxony (Georg-August-Universität Göttingen), *NW* North Rhine-Westphalia (Universität Duisburg-Essen), *RP* Rhineland-Palatinate (Johannes Gutenberg-Universität Mainz), *SL* Saarland (Universität des Saarlandes), *SN* Saxony (Universität Leipzig), *ST* Saxony-Anhalt (Martin-Luther-Universität Halle-Wittenberg), *SH* Schleswig-Holstein (Christian-Albrechts-Universität zu Kiel), *TH* Thuringia (Friedrich-Schiller-Universität Jena)
[a]State examination instead of a consecutive degree program

3.2 Participants

A total of 1004 students from a southwestern German university took part in the study. After an initial data check, 53 participants were excluded because they were not enrolled in the teacher education program. The final set comprised 951 pre-service teachers (63 % female and 37 % male). Their mean age was 21.98 years (SD = 2.63), and they had studied for an average of 3.79 semesters (SD = 3.38). Twenty-one percent of the participants had already completed their compulsory 6-month school-based training.

3.3 Instrument

The newly developed instrument consisted of three sections: (1) pre-service teachers' perception of their understanding of school development (39 items; e.g., school autonomy, curriculum, management), with the items answered on a 4-point Likert scale (1 = no understanding, 4 = very high understanding); (2) strength of relationship between specific items focusing on school development (e.g., curriculum–school development), with the strengths of relationship answered on an 11-point scale (1 = minimal relation, 11 = maximal relation); and (3) socio-demographic information such as age, gender, and study-related items, as well as participation in the 6-month compulsory school-based training program.

3.4 Data Analysis

To analyze the first section of the questionnaire (pre-service teachers' perception of their understanding of school development), we conducted an exploratory factor analysis on the 39 items with orthogonal rotation (varimax) to identify clusters of variables. The Kaiser–Meyer–Olkin measure and the Bartlett's test of sphericity verified the sampling adequacy for the analysis (KMO = .93, χ^2 (666) = 11371.75, $p < .001$). Seven factors in the data had eigenvalues over Kaiser's criterion of 1 and in combination explained 53.42 % of the variance. The scree plot showed inflections, which would justify a four-factor model. The four extracted factors represent 44.15 % of the variance (see Table 5.2). Two items were removed due to construct considerations.

The first factor, encompassing 13 items, refers to the understanding of *classroom organization and management* and explains 12.93 % of variance (Cronbach's $\alpha = .84$). It combines aspects such as classroom climate, lessons, parents, and compulsory control. Factor two represents the understanding of *school management* and is determined by 13 items explaining 12.92 % of variance (Cronbach's $\alpha = .87$). It comprises aspects referring to the school level, such as project management, school assessments, and school board. The third factor refers to the understanding of *curriculum* and explains 9.78 % of variance (Cronbach's $\alpha = .79$). It is composed of seven items, such as core curriculum, educational plan, and educational policy. The fourth factor represents the understanding of *administration* and is determined by four items, such as school principals and parents' council. It explains 8.52 % of variance (Cronbach's $\alpha = .61$). The identified subscales were classified according to the questionnaire's 4-point Likert scale. Table 5.2 depicts an overview of the factors, the items loading on them, and the reliabilities.

Regarding the second part of the questionnaire (strength of relationship between specific items focusing on school development), we conducted another exploratory factor analysis (varimax rotation) on the 39 items that showed strength of relationship with regard to school development. The Kaiser–Meyer–Olkin measure and the Bartlett's test of sphericity verified the sampling adequacy for the analysis (KMO = .90, $\chi 2$(666) = 11685.55, $p < .001$). Nine factors in the data had eigenvalues over Kaiser's criterion of one and in combination explained 61.07 % of the variance. A three-factor solution was considered as most appropriate. The three extracted factors represent 40.13 % of the variance (see Table 5.3). Two items were removed due to construct considerations.

Table 5.2 Overview of the four factors, reliabilities, factor loading, and items (first section of the questionnaire)

Factor	Loading	Items
1. Classroom organization and management	.699	Classroom climate
(13 items, $\alpha = .84$)	.684	Class representative
	.624	Class
	.587	School climate
	.561	Parents' evening
	.550	Working group
	.531	Compulsory control
	.520	Lessons
	.488	Class conference
	.471	Parents
	.461	Equal opportunities
	.395	School profile
	.351	Guiding model
2. School management	.715	Organizational development
(13 items, $\alpha = .87$)	.688	Project management
	.594	School administration
	.535	Cooperation
	.535	School autonomy
	.526	Staff council
	.474	School organization
	.468	School board
	.466	Education authority
	.460	School supervising
	.446	School assessment
	.423	School law
	.376	Further education
3. Curriculum	.712	Core curriculum
(7 items, $\alpha = .79$)	.699	School curriculum
	.680	Educational plan
	.550	Syllabus
	.482	Specialist subject teacher conference
	.480	School staff meeting
	.408	Educational policy
4. Administration	.633	Parents' council
(4 items, $\alpha = .61$)	.632	School principals
	.619	Upper level's school office
	.326	Compulsory education

Table 5.3 Overview of the three factors, reliabilities, factor loading, and items (second section of the questionnaire)

Factor	Loading	Items
1. Class level	.688	Class conference–school development
(15 items, $\alpha = .86$)	.641	Parents' evening–school development
	.639	Class–school development
	.628	Classroom climate–school development
	.584	Class representative–school development
	.568	Working group–school development
	.525	Lessons–school development
	.516	Parents–school development
	.512	Compulsory control–school development
	.490	School climate–school development
	.466	Further education–school development
	.448	Equal opportunity–school development
	.426	Teacher–school development
	.395	School supervising–school development
	.393	Parents' council–school development
2. School level	.681	School administration–school development
(12 items, $\alpha = .85$)	.675	Organizational development–school development
	.631	Project management–school development
	.613	Cooperation–school development
	.604	Staff council–school development
	.591	School profile–school development
	.580	School board–school development
	.557	Guiding model–school development
	.524	School autonomy–school development
	.520	School assessment–school development
	.485	School curriculum–school development
	.314	School principals–school development
3. Educational policy level	.751	Education authority–school development
(10 items, $\alpha = .83$)	.705	Educational plan–school development
	.686	Syllabus–school development
	.663	School law–school development
	.658	Educational policy–school development
	.571	Upper level's school office–school development
	.531	Compulsory schooling–school development
	.404	School staff meeting–school development
	.394	Core curriculum–school development
	.359	Specialist subject teacher conference–school development

Factor one represents the *class level* and is determined by 15 items, such as relation between classroom climate and school development, relation between class conference and school development, or relation between parents and school development. It explains 8.25 % of variance (Cronbach's $\alpha = .86$). The second factor is named *school level* and comprises 12 items. It shows strength of relationship with regard to school development for items such as school administration–school development, organizational development–school development, and school assessment–school development. It explains 25.65 % of variance (Cronbach's $\alpha = .85$). Factor three represents the *educational policy level*. It encompasses ten items, such as educational plan–school development, compulsory education–school development, and school law–school development. It explains 6.23 % of variance (Cronbach's $\alpha = .83$).

The identified subscales were classified according to the questionnaire's 11-point Likert scale. For an overview of the factors, the items loading on them, and the reliabilities, see Table 5.3.

Descriptive statistics were applied to test Hypothesis 1a and Hypothesis 3. We conducted a Kruskal–Wallis H-test to test Hypothesis 1b and independent-samples t-tests to test Hypothesis 2 and Hypothesis 4. Initial data checks showed that the distributions of ratings and scores satisfied the assumptions underlying the analysis procedures. All effects were assessed at the .05 level, and effect sizes were reported where appropriate.

4 Results

4.1 Pre-Service teachers' Perception of Their Understanding of School Development

Table 5.4 provides mean scores and standard deviations for the four subscales (classroom organization and management, school management, curriculum, administration). The subscale classroom organization and management shows the highest score ($M = 2.19$, SD = .52) and the subscale school management the lowest score ($M = 1.58$, SD = .57).

In general, the participants rated their understanding of school development rather low. The highest ranked subscale was classroom organization and management (i.e., classroom climate, lessons), even though the mean score reflects little understanding with regard to the 4-point Likert scale. The participants' understanding of school management (e.g., project management, school assessments, school board) is even lower. These findings reinforce our assumption that pre-service teachers lack substantial understanding of school development (Hypothesis 1a).

Regarding Hypothesis 1b, we computed a Kruskal–Wallis H-test to determine whether the participants' understanding of school management varied as a function of whether they had understanding in classroom organization and management, curriculum, or administration. Results of the analysis revealed significant differences for classroom organization and management, $\chi^2(2) = 134.663$, $p < .001$, $\omega = .40$

Table 5.4 Means and standard deviations for the subscales classroom organization and management, school management, curriculum, and administration ($N = 844$)

Subscale	M	SD
Classroom Organization and Management	2.19	.52
School Management	1.58	.57
Curriculum	1.81	.61
Administration	1.85	.57

Note. Scale ranges from 1 = no understanding to 4 = very high understanding

Table 5.5 Results of independent-samples *t*-test for differences in understanding between school-based training and no school-based training ($N = 799$)

	School-based training							
	Yes			No				
	M	SD	*n*	*M*	SD	*n*	95 % CI	*t(797)*
Classroom Organization and Management	2.20	.58	165	2.18	.51	634	−.062, .093	−.373
School Management	1.61	.61	165	1.57	.56	634	−.102; .063	−.676
Curriculum	2.08	.67	165	1.73	.67	634	−.446; −.270	−6.670***
Administration	1.87	.63	165	1.85	.63	634	−.102; .065	−.391

Note. Scale ranges from 1 = no understanding to 4 = very high understanding; ***$p < .001$

(moderate effect), curriculum, $\chi^2(2) = 224.054$, $p < .001$, $\omega = .51$ (strong effect), and administration, $\chi^2(2) = 174.824$, $p < .001$, $\omega = .46$ (moderate effect). Mann–Whitney post hoc comparisons indicated that the participants had significantly higher understanding in classroom organization and management, curriculum, and administration than in school management (see Table 5.4 for descriptive statistics). Accordingly, the findings support Hypothesis 1b, indicating that the pre-service teachers have a lower understanding of school development in the area of school management when compared to their understanding in classroom organization and management, curriculum, or administration.

Regarding Hypothesis 2, we conducted four independent-samples t-tests to compare the perceived understanding of pre-service teachers who had already completed their school-based training and those who had not (see Table 5.5). For the subscale curriculum, there was a significant difference in perceived understanding between pre-service teachers with professional experience ($M = 2.08$, SD = .67) and those without ($M = 1.73$ SD = .58), $t(797) = -6.670$, $p < .001$, $d = .59$ (medium effect). No significant differences were found for the subscales classroom organization and management, school management, and administration. Accordingly, the results support Hypothesis 2 with regard to the subscale curriculum. Overall, the low mean scores of all subscales indicate that even after the initial school-based training, pre-service teachers do not have a deep understanding in the areas of classroom organization and management, school management, curriculum, and administration.

4.2 Strength of Relationship Between Educational Levels with Regard to School Development

Table 5.6 summarizes the mean scores and standard deviations for the three educational levels (classroom level, school level, educational policy level) with regard to school development. The school level ranks highest ($M=7.0$, SD = 1.42), closely followed by the educational policy level ($M=6.66$, SD = 1.57) and the classroom level ($M=5.85$, SD = 1.41). Thus, the results suggest that pre-service teachers assume the school level to be the most relevant educational level for school development. However, all three educational levels show similar mean scores ($M=5.85$ to $M=7.0$). This could indicate either that pre-service teachers suppose that all levels are approximately equally relevant for school development or that they scored towards the midpoint of the 11-point Likert scale because they lack a deep understanding of school development.

Hence, the results support our assumption that pre-service teachers fail to differentiate sufficiently between educational levels with regard to school development. The central tendency error reinforces Hypothesis 3.

We computed three independent-samples t-tests in order to test the fourth Hypothesis (different assessment of educational levels with regard to school development for pre-service teachers with and without school-based training) (see Table 5.7). A significant difference was found for the *school level* between pre-service teachers who had completed their school-based training ($M=7.27$, SD = 1.59) and those who had not ($M=6.94$, SD = 1.38), $t(-2.50)=-246.26$, $p<.001$, $d=.23$ (small effect). There were significant differences neither for the *classroom level* nor for the *educational policy level* regarding school development.

According to Hypothesis 4, we expected significantly different rankings for all three educational levels. However, the results show only one significant difference for the strengths of relationship with regard to school development. Pre-service

Table 5.6 Means and standard deviations for the subscales classroom level, school level, and educational policy level ($N=809$)

Subscale	M	SD
Classroom level	5.85	1.41
School level	7.00	1.42
Educational policy level	6.66	1.57

Note. Scale ranges from 1 = minimal relation to 11 = maximal relation

Table 5.7 Results of independent-samples *t*-test for different assessment of educational levels with regard to school development between school-based training and no school-based training ($N = 767$)

	School-based training							
	Yes			No				
	M	SD	*n*	*M*	SD	*n*	95 % CI	*t*(765)
Classroom level	5.99	1.42	170	5.83	1.41	597	−.399; .085	−1.276
School level	7.27	1.59	170	6.94	1.38	597	−.599, .070	−2.697***
Educational policy level	6.46	1.69	170	6.71	1.55	597	−.024; .516	−1.788

Note. Scale ranges from 1 = minimal relation to 11 = maximum relation; ***$p < .001$

teachers who had completed their school-based training assessed the school level as significantly more important than did pre-service teachers with primarily theoretical understanding based on their university education. However, the small effect size indicates that even 6 months of professional experience in school does not contribute to an in-depth understanding of the complexity and interrelatedness of all educational levels influencing school development. Apparently, the inadequate implementation of theoretical frameworks focusing on school development at German universities (Terhart, 2012) might be confirmed for school-based training courses at German schools too.

5 Discussion

Research on the effects of pre-service teachers' education covers a wide range of topics, for example, the effectiveness of pre-service education, what pre-service teachers learn during their internship at schools, or what kind of problems pre-service teachers have to cope with at various stages of their education (Bravo, Mosqueda, Solís, & Stoddart, 2014; Hascher, 2006, 2012; Jones, 1982; Zeichner, 1986; Zeichner & Tabachnik, 1985). However, there has been little empirical research focusing on pre-service teachers' understanding of school development. Therefore, this study examined pre-service teachers' subjective understanding of school development.

First, we analyzed pre-service teachers' perception of their understanding of school development. The exploratory factor analysis identified a four-factor model (classroom organization and management, school management, curriculum, and administration). We determined that the pre-service teachers' self-estimated understanding of these constructs is rather low (Hypothesis 1 and 2).

Second, we wanted to examine how pre-service teachers assess different educational levels of school development and whether there are differences among pre-service teachers who have completed their school-based training. The exploratory factor analysis showed three educational levels (classroom level, school level, educational policy level). Findings show that pre-service teachers tend to assess all levels towards the middle of the Likert scale. They hesitated to classify them at either end of the scale (minimal relation or maximal relation with regard to school development) (Hypothesis 3). Further, not even a 6-month school-based training program provides deeper understanding of the complexity and interrelatedness of factors influencing school development (Hypothesis 4).

5.1 Practical Implications

Our observations have several practical implications for pre-service teachers' education. We suggest a competency-based training program focusing on school development. This training program should include a game-based learning environment for facilitating a deeper understanding of school development and further developing necessary competencies. The underlying game engine should be designed as a computer-based modeling tool in order to facilitate deep understanding (Jonassen, 1999). The goal of the game is to improve the efficiency of a school by investing time, effort, and money in different areas of the school and, as a result, reducing its dropout rate as well as increasing its efficiency (Ifenthaler, 2009). Attewell and Seel (2003) emphasize the problem of school dropout as an important issue in modern society. Accordingly, as the target group of the game are pre-service teachers, the chosen scenario provides a direct link to their professional life. Learning goals include mental simulations, refinement of the learner's model of school development, the realization of the school dropout problem, and the accretion, tuning, and restructuring of underlying knowledge structures. The implementation of the above-described game in the teacher education curriculum may be expected to advance the pre-service teachers' overall understanding of school development prior to their school-based internship.

Further, the pre-service teacher education curriculum should be advanced through the implementation of stronger collaboration between pre-service and in-service teachers using social media platforms (Chen, 2012). This vertical professional collaboration (pre-service teachers and in-service teachers) focusing on school development is expected to facilitate a deeper understanding of school development through mentoring and modeling (Lambson, 2010).

5.2 Limitations and Suggestions for Future Research

This study has obvious limitations that require consideration, primarily with regard to sample characteristics and methodological issues. First, the sample included a select group of participants from one university, thus prohibiting a generalization of results. Future studies across institutions are required, so that more general conclusions can be drawn. Second, the perception of understanding is biased and does not reflect the competencies of pre-service teachers. As an initial investigation of the field, we analyzed pre-service teachers' self-rated understanding of different aspects of school development. Future research should include in-depth analysis of pre-service teachers' knowledge and competencies in the area of school development. Third, we conducted two exploratory factor analyses to investigate the variable structures of the questionnaire. The first section (pre-service teachers' perception) showed a four-factor solution as most appropriate, the second section (strengths of relationships) a three-factor extraction. Sample sizes of 500 are seen as very good and 1000 or more as excellent (Comrey & Lee, 1992). The sample size of the study ($N=951$) is acceptable, but there is no evidence that both factor structures can be replicated and therefore generalized. We suggest directly estimating the replicability (Osborne, 2014).

5.3 Conclusion

As research in teacher education suggests (Ertmer, 2005; Kim, Kim, Lee, Spector, & DeMeester, 2013), providing pre-service teachers with practice opportunities and offering competency-based support and demonstrations of example cases, both through face-to-face and virtual means, can enable them to better understand the complexity of school development and become more successful educators. However, an in-depth understanding of the complexity and interrelationships of factors influencing school organization and development is a prerequisite for successfully responding to constant change within schools, where teachers are expected to play an integral part. In order to prepare teachers for constant innovation in twenty-first century schools, curricula for teacher education must be tailored to reflect the multifaceted competencies teachers should possess on the system, school, classroom, and individual levels.

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Part II
Changing Learning and Instructional Paradigms

Chapter 6
School Analytics: A Framework for Supporting School Complexity Leadership

Stylianos Sergis and Demetrios G. Sampson

Abstract Data-driven decision-making in education has received an increasing level of attention on a global scale, especially with the raising interest on big data. This trend has led to the development of two core analytics strands, namely Academic Analytics and Learning Analytics. The former focuses mainly on the macro layer of the organization and is addressed to higher education, while the latter focuses mainly on the micro/meso layers of the organization. Considering the diverse focal points and contexts of application of the two existing analytics strands, the ecosystemic nature of K-12 schools as social complex adaptive systems, as well as, the need for data-based evidence-driven school complexity leadership, we claim that a holistic decision support approach for addressing the full spectrum of school leaders' tasks is required, beyond the existing analytics strands. Therefore, in this book chapter, we introduce the concept of School Analytics as a holistic, multilevel analytics framework aiming to integrate data collected from all micro-, meso- and macro- organizational layers. We analyze them in an intertwining manner towards providing continuous feedback loops and systemic decision support to K-12 school leaders.

Keywords Academic analytics • Data-driven decision-making • Learning analytics • School analytics • School complexity leadership

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1 Introduction

Data-driven decision making (DDDM) in Education has received an increasing level of attention, on a global scale (Lai & Schildkamp, 2013). As a process, it refers to the collection, analysis, and interpretation of institution-wide data towards generating insights and knowledge for informing practice and leadership in educational settings (Mandinach, 2012). More specifically, within social complex adaptive systems such as educational institutions (Snyder, 2013), these data are generated by a multitude of interrelated agents (e.g., teachers, leaders, students, parents, official policies, infrastructural aspects) and are harvested mainly from three institution layers, as follows:

- **Micro layer**, which refers to the *learning and assessment practices* occurring either within the physical educational organization premises or beyond them (Kaufman, Graham, Picciano, Popham, & Wiley, 2014; Mandinach, 2012; Van der Kleij, Vermeulen, Schildkamp, & Eggen, 2015). At the micro layer, DDDM is primarily targeted at harvesting student educational data towards facilitating the teacher (or faculty) to provide better learning experiences to students and, eventually, support them in achieving better performance, interactions, progress, and outcomes (Schildkamp, Karbautzki, & Vanhoof, 2014).
- **Meso layer**, which refers to the *monitoring and evaluation of the teaching practices and curriculum planning* of the school (Ifenthaler & Widanapathirana, 2014). At the meso layer, DDDM is primarily targeted at facilitating the school leadership team to analyze and assess the teaching practices (e.g., educational designs and overall curriculum) that are employed in the educational organization.
- **Macro layer**, which refers to the *organizational development processes* of the educational organization (Kaufman et al., 2014). At the macro layer, DDDM is primarily targeted at facilitating the school leadership team to strategically delineate the organizational business intelligence, e.g., staff professional development (Schildkamp & Kuiper, 2010) or infrastructural resource planning (Breiter & Light, 2006; Lai & Schildkamp, 2013).

Employing data-driven decision making processes, or *Analytics* as it is usually referred to (Ravishanker, 2011; van Barneveld, Arnold, & Campbell, 2012), is considered to be instrumental towards effective organizational complexity leadership, since it can provide a solid basis for formulating and sustaining essential interaction and communication channels within the school system agents (Lai & Schildkamp, 2013; Pistilli, Willis, & Campbell, 2014; Uhl-Bien, Marion, & McKelvey, 2007). These channels provide continuous feedback loops to these agents (and the leadership team in particular) and are at the core of sustainable School Complexity Leadership by enabling and monitoring the *emergence* of the system—that is to say, the current status of the system, which is not a linear sum of its constituent parts but has been forged in a networked and unpredictable manner by the characteristics and interactions of its agents (Uhl-Bien & Marion, 2009). As a result, the research community has been striving towards identifying effective analytics methods for supporting leadership decision-making through the collection and exploitation of institution-wide data (e.g., Cosic, Shanks, & Maynard, 2012).

Towards addressing the aforementioned goal in an *educational context*, the concept of analytics has spawned two core strands, namely Learning Analytics (LA) and Academic Analytics (AA) (Ferreira & Andrade, 2014; Long & Siemens, 2011; Norris & Baer, 2013). *Learning Analytics* are addressed to all types of educational institutions (e.g., K-12 schools and Higher Education Institutions—HEI), as well as online education (e.g., Massive Open Online Courses—MOOCs), and mainly aim at providing data-driven decision support for the micro/meso layers (Long & Siemens, 2011). *Academic Analytics*, on the other hand, are specifically addressed to HEI and mainly aim at providing data-driven decision support on a macro layer related to the Business Intelligence of the organization (Daniel, 2015; Siemens, 2013).

However, when the focus of study is narrowed down to K-12 schools, the aforementioned analytics strands do not appear to be able to adequately support K-12 school complexity leadership. This hypothesis is based on the fact that K-12 school leaders require *holistic* data-driven decision support in order to effectively engage with their complex tasks, given the ecosystemic nature of schools as social complex adaptive systems (Huang & Kapur, 2012; Sergis & Sampson, 2014a; Trombly, 2014). More specifically, these tasks require highly granulated data collection and processing from all institutional layers towards generating continuous feedback loops and communication channels. The latter two, that can be exploited by school leaders for driving systemic school development and monitoring the state of the schools' emergence towards strategic insights (McQuillan, 2008; Miller & Page, 2007). In addition to this, school autonomy and accountability are being globally pursued and promoted, thus assigning school leaders with higher levels of responsibility than before (Hooge, Burns, & Wilkoszewski, 2012). Lastly, school leaders' decision-making capabilities are hindered by the fact that existing decision support systems have not yet reached their full potential to support the full spectrum of school leaders' tasks (Kaufman et al., 2014; Sergis & Sampson, 2016a).

Under the light of the above, it becomes evident that the two existing analytics strands do not offer the capacity for the *holistic* decision support required by K-12 school complexity leadership, given their isolated focal points and leadership objectives. Therefore, the contribution of this book chapter is the proposal for a new educational analytics framework, namely *School Analytics* which aims at tackling this shortcoming and, thus, facilitate K-12 school complexity leadership. School Analytics are presented as a holistic multilevel analytics framework aiming to integrate and analyze "Business" Intelligence (macro layer) data and Educational/Learning (micro/meso layers) data in an intertwining manner towards the provision of more granulated feedback loops to the school leadership. These feedback loops, which require highly granulated and continuous mechanisms for capturing, analyzing, and exploiting institution-wide educational data, can allow for the school leaders to monitor and (partially) influence the emergence states of their school towards meeting the needs of the school system agents (e.g., students, teachers, parents, external policy mandates).

The remainder of the book chapter is as follows. Section 2 defines the background of this work, namely the definitions and main objectives and methods of analysis of Academic Analytics and Learning Analytics. Additionally, for each analytics strand, a review of indicative existing systems is performed towards identifying the level of accommodation provided for their respective objectives. Section 3 presents the background of school complexity leadership and the proposed School Analytics concept in terms of focal points and objectives towards facilitating K-12 school complexity leadership data-driven decision making. Moreover, potential implications of the School Analytics are discussed in towards the design of systems offering systemic school leadership support affordances. Finally, Sect. 4 presents the conclusions drawn and suggests future work in this agenda.

2 Background: Analytics in Education

The following subsections describe the two core educational analytics strands, namely Academic Analytics (AA) and Learning Analytics (LA). Each of the two strands are analyzed in terms of focal points and key leadership objectives they aim at supporting, through the provision and exploitation of data generated in all layers of educational institutions.

2.1 Academic Analytics

2.1.1 Academic Analytics Definition

Academic Analytics refer to data-driven decision-making practices for informing operational purposes at the Higher Education level (Baepler & Murdoch, 2010). Academic Analytics are addressed at providing HEI leaders with support for managing the processes of the macro institutional layer, namely the "Business Intelligence" (Chatti, Dyckhoff, Schroeder, & Thüs, 2012; Elias, 2011; Goldstein & Katz, 2005; Siemens, 2013). These processes primarily refer to operational and financial decision-making (Ferreira & Andrade, 2014; van Barneveld et al., 2012). A similar term used in the literature is that of Action Analytics which considers similar data and decisions at a macro layer towards the generation of informed insights (Norris, Baer, & Offerman, 2009). For the context of this book chapter, the term Academic Analytics will also incorporate Action Analytics.

Therefore, existing Academic Analytics approaches are directly linked to orchestrating organizational processes such as student admission and management, finance and fundraising, faculty management and infrastructure procurement (Chatti et al., 2012; Daniel, 2015; Goldstein & Katz, 2005; Macfadyen & Dawson, 2012; Siemens et al., 2011).

2.1.2 Academic Analytics methods and objectives

Academic Analytics approaches have largely relied on specific data analysis methods, namely data mining, statistical analysis and predictive modeling (Baepler & Murdoch, 2010; Campbell, DeBlois, & Oblinger, 2007; Daniel, 2015). These analysis methods have been primarily exploited in order to address a set of core objectives of Academic Analytics, focusing on the macro layer tasks of the HEI. This set of core Academic Analytics objectives is presented below, in terms of general description, required data types, as well as the purpose for which they are being pursued:

- **AA–O1. Student Management:** This objective relates to the facilitation of HEI leadership to manage the diverse set of student data.

- *Common data types* utilized are

  – Demographic data (Campbell et al., 2007),
  – Admission and past academic records (Antons & Maltz, 2006; Bohannon, 2007; Goldstein & Katz, 2005),
  – Course enrollment status (bin Mat, Buniyamin, Arsad, & Kassim, 2013; Pirani & Albrecht, 2005; Ravishanker, 2011) and
  – Grants administered (Antons & Maltz, 2006; Norris, Baer, Leonard, Pugliese, & Lefrere, 2008).

Main Purpose: Apart from the evident need of HEI leadership to keep track of their student's data, Academic Analytics have moved beyond mere capturing of these data towards providing insights. Regarding student admissions in particular, Academic Analytics can offer informed predictive recommendations on the best student candidates, based on their previous academic performance and standardized test results (Bichsel, 2012; Campbell & Oblinger, 2007; Vialardi et al., 2011). Additionally, Academic Analytics have utilized predictive modeling techniques in order to predict future admission and enrollment rates, towards strategically allocating available resources (Campbell et al., 2007; Norris et al., 2008).

- **AA–O2. Infrastructure management:** This objective refers to the management of the available infrastructure and the provision of insights for targeted maintenance and/or update (Goldstein & Katz, 2005).
- *Common data types* utilized are:

  – The quantity and quality of physical and digital resources, such as IT equipment (Campbell & Oblinger, 2007) and library resources (Bichsel, 2012).
  – The aggregated level of usage of these resources (Bichsel, 2012; Campbell & Oblinger, 2007).

Main Purpose: An evident purpose to oversee the quality of the HEI infrastructure relates to the need to replace or update potentially "out-of-order" resources, either physical (e.g., computers) or digital (e.g., the HEI Learning Management System). Apart from this, these data can also be utilized in conjunction with other HEI function areas and provide insights, such as delineating more efficient admission and enrollment plans in order to optimize resource allocations (Campbell et al., 2007; Long & Siemens, 2011).

- **AA–O3. Faculty management:** This objective primarily relates to facilitating HEI leadership to oversee and potentially support faculty in terms of performance, i.e., research and teaching (Bichsel, 2012).
- *Common data types* utilized are
  - Faculty demographic data (Dziuban, Moskal, Cavanagh, & Watts, 2012)
  - Quality and quantity of research conducted (Campbell & Oblinger, 2007; Long & Siemens, 2011), and
  - Student academic performance and course enrollment as an indicator for evaluating teaching performance (Dziuban et al., 2012; Howlin & Lynch, 2014; Pirani & Albrecht, 2005).

Main Purpose: Apart from the evident rationale of internal HEI management and improvement (including faculty professional development and hiring), exploitation of the aforementioned data can be crucial for the HEI in terms of meeting external accountability goals (Ferreira & Andrade, 2014; Gašević, Dawson, & Siemens, 2015). Therefore, HEI leadership can utilize the insights generated towards remedying actions, such as targeted curriculum (or course) improvement (Bichsel, 2012).

- **AA–O4. Financial management:** This objective mainly aims to provide decision support for orchestrating the financial action plan (Bichsel, 2012; Long & Siemens, 2011; Pirani & Albrecht, 2005).
- *Common data types* utilized are
  - Students' tuition fees and grants (Barber & Sharkey, 2012; bin Mat et al., 2013; Forsythe, Chacon, Spicer, & Valbuena, 2012),
  - Faculty-related costs, such as salary, professional development costs and research funds (Campbell & Oblinger, 2007)
  - Infrastructure maintenance and procurement costs (Campbell & Oblinger, 2007) and
  - External alumni or sponsor fundraising (Bichsel, 2012; Bohannon, 2007).

Main Purpose: The main purposes driving the harvesting and exploitation of the abovementioned data types include:

- The provision of alerts when the financial plan of the organization sidetracks (Goldstein & Katz, 2005),
- Utilization of these data in conjunction with other HEI function areas, such as enrollment prediction and optimal resource allocation (Bichsel, 2012; Bohannon, 2007; Forsythe et al., 2012; Norris et al., 2008)
- Facilitation of HEI leadership to identify sources of external sponsorship with a higher possibility to donate funds to the organization using predictive modeling techniques (Campbell et al., 2007).

- **AA–O5. Student retention:** One of the most common objectives of Academic Analytics is the monitoring of the student retention rates and the provision of decision support to HEI leadership towards remedying actions, in case of low such levels (Campbell & Oblinger, 2007; Lauría, Baron, Devireddy, Sundararaju, & Jayaprakash, 2012; Taylor & McAleese, 2012). More specifically, by utilizing data mining and predictive modeling techniques, Academic Analytics can process a wide range of student data towards predicting the possibility of each student to drop out from a course (Arnold, 2010; bin Mat et al., 2013; Macfadyen & Dawson, 2010; Smith, Lange, & Huston, 2012).

- *Common data types* utilized are
  - Student demographics (Jayaprakash, Moody, Lauría, Regan, & Baron, 2014),
  - Student financial data, including grants provided and prior financial capacity (Barber & Sharkey, 2012),
  - Assessment results (Baepler & Murdoch, 2010; Jayaprakash et al., 2014),
  - Level of engagement in learning activities (Arnold, 2010; Graf, Ives, Rahman, & Ferri, 2011; Phillips et al., 2010)
  - Prior academic performance (Ice et al., 2012)

Main Purpose: Mining, analyzing, and visualizing the abovementioned data types can facilitate HEI leadership by:

- Generating "early alerts" for students that appear to be lagging in terms of their academic performance and to provide warnings that will potentially lead to remedying actions (Arnold & Pistilli, 2012; Baepler & Murdoch, 2010; Frankfort, Salim, Carmean, & Haynie, 2012; Howlin & Lynch, 2014; Norris et al., 2008)
- Providing correlations between individual students' performance to peers' can also highlight potential shortcomings (Baepler & Murdoch, 2010; Jayaprakash et al., 2014)
- Generating recommendations of more appropriate educational pathways can also be provided to the students and student tutors (Bramucci & Gaston, 2012; Vialardi et al., 2011)
- Facilitating the process of curriculum re-structuring to address common student performance problems (Bichsel, 2012; Daniel, 2015; Howlin & Lynch, 2014).

Finally, the above data analyses can assist HEI leadership to meet the institution's internal improvement plan (Campbell & Oblinger, 2007), as well as its external accountability goals (Bahr, 2012; Ice et al., 2012; Norris & Baer, 2013).

The analysis of key objectives of Academic Analytics supports the initial statement that, apart from its explicit focus on HEI, existing Academic Analytics approaches have focused on orchestrating the Business Intelligence of the macro organizational layer. This can be (at least partly) attributed to the common mandates regarding external accountability, which mainly include (a) reporting the level of quality of operations to policy makers and funders (Ferreira & Andrade, 2014; Gašević et al., 2015; Norris et al., 2009) and (b) achieving high rankings in inter-HEI benchmarks which are largely based on a diverse set of data (e.g., staff-to-student ratio, research quality/quantity, resource allocation per student, alumni professional success) (Daniel, 2015; Siemens, 2013). On the other hand, explicit orchestration of the teaching and learning processes of the micro/meso layers of the HEI is not robustly addressed and supported by Academic Analytics approaches.

Table 6.1 Consolidated overview of academic analytics objectives and related elements

AA objective	Common data types utilized	Main purposes	Role involved
O1. Student Management	• AA-O1-DT1. Demographic data	• AA-O1-P1. Overview of student's data	HEI leaders
	• AA-O1-DT2. Admission and past academic records	• AA-O1-P2. Recommend best student candidates	HEI faculty
	• AA-O1-DT3. Course enrollment status	• AA-O1-P3. Predict admission/enrollment rates	
	• AA-O1-DT4. Grants administered		
O2. Infrastructure management	• AA-O2-DT1. Quantity and quality of physical and digital resources	• AA-O2-P1. Overview of HEI infrastructure	
	• AA-O2-DT2. Level of usage of resources	• AA-O2-P2. Recommend resource procurement/maintenance	
		• AA-O2-P3. Recommend resource allocation in terms of admissions/enrollments	
O3. Faculty management	• AA-O3-DT1. Faculty demographic data	• AA-O3-P1. Overview of faculty data	
	• AA-O3-DT2. Quality and quantity of research conducted	• AA-O3-P2. Highlight underperforming faculty in terms of HEI standards	
	• AA-O3-DT3. Student academic performance and course enrollment	• AA-O3-P3. Highlight curriculum/course shortcomings	
O4. Financial management	• AA-O4-DT1. Student tuition fees and grants	• AA-O4-P1. Alert provision when the financial plan of the organization sidetracks	
	• AA-O4-DT2. Faculty-related costs	• AA-O4-P2. Financial resource allocation based on admission/enrollment prediction	
	• AA-O4-DT3. Infrastructure maintenance and procurement costs	• AA-O4-P3. Identification of external sponsors	
	• AA-O4-DT4. Alumni or sponsor fundraising		
O5. Student retention	• AA-O5-DT1. Student demographics	• AA-O5-P1. Generate "early warning alerts" to underperforming students	HEI leaders
	• AA-O5-DT2. Student financial data	• AA-O5-P2. Correlate individual students' performance to peers'	HEI faculty
	• AA-O5-DT3. Student assessment results	• AA-O5-P3. Recommend educational pathways	HEI student
	• AA-O5-DT4. Student level of engagement in learning activities	• AA-O5-P4. Facilitate the process of curriculum re-structuring	
	• AA-O5-DT5. Student prior academic performance		

Table 6.1 provides a consolidated overview of the above analysis of Academic Analytics objectives, towards:

- Supporting Sect. 2.1.3, which presents an analysis of an indicative examples of existing Academic Analytics systems. The purpose of this analysis is to identify the level of accommodation that these systems' functionalities provide in terms of each Academic Analytics objective and identify potential shortcomings,
- Providing a basis for formulating the proposed School Analytics framework (Sect. 3) by highlighting the objectives of Academic Analytics which could be useful for supporting the macro layer K-12 school leadership tasks.

2.1.3 Academic Analytics systems

Table 6.2 presents the analysis of an indicative sample of 7 AA systems and/or initiatives, in terms of the level of accommodation that the functionalities offered for each AA objective.

As Table 6.2 depicts, the indicative sample of Academic Analytics systems/initiatives robustly supports only a fraction of Academic Analytics objectives, i.e., the HEI leadership tasks related to student management and retention. The tasks related to faculty management and financial orchestration have received less attention, although they are however, significantly supported.

Two identified shortcomings include:

- The limited level of accommodation for the tasks related to the orchestration of the HEI infrastructure. This is deemed significant since this macro layer aspect can have a significant impact of the overall organizational performance (Pelgrum, 2008).
- The limited level of holistic approaches for exploiting the macro layer data in combination, i.e., moving beyond harvesting and exploiting each data type in isolation (or with a restricted set of other data) towards facilitating systemic leadership decision support.

2.2 Learning Analytics

2.2.1 Learning Analytics Definition

Learning Analytics refer to the measurement, collection, analysis, and reporting of data about learners and their contexts of learning, for purposes of understanding and optimizing learning as well as the environment in which it occurs (Long & Siemens, 2011). As the above definition suggests, LA have a different core focal point compared to Academic Analytics, namely they are targeted at the micro layer and meso layer of an educational institution (Daniel, 2015; Long & Siemens, 2011). Therefore, LA takes a standpoint primarily aimed at exploiting student-generated data towards monitoring and scaffolding students' progress, as well as improving the overall

Table 6.2 Overview of indicative sample of Academic Analytics Systems

#	AA system	AA objective addressed	AA data type harvested		AA purpose targeted
1	Course Signals[a] (Arnold, 2010)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2	• AA-O1-DT3	• AA-O1-P1
		O3. Faculty management	• AA-O3-DT2		–
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT3	• AA-O5-DT4 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2 • AA-O5-P4
2	Bowie State University (Forsythe et al., 2012)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2	• AA-O1-DT3 • AA-O1-DT4	• AA-O1-P1
		O3. Faculty management	• AA-O3-DT2		• AA-O3-P1 • AA-O3-P2
		O4. Financial management	• AA-O4-DT1		• AA-O4-P1 • AA-O4-P2
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT2 • AA-O5-DT3	• AA-O5-DT4 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2 • AA-O5-P3 • AA-O5-P4
3	University of Maryland Eastern Shore (Forsythe et al., 2012)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2	• AA-O1-DT3 • AA-O1-DT4	• AA-O1-P1 • AA-O1-P3
		O3. Faculty management	• AA-O3-DT2		• AA-O3-P1
		O4. Financial management	• AA-O4-DT1		• AA-O4-P1 • AA-O4-P2
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT2	• AA-O5-DT3 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2

4	RIO PACE (Smith et al., 2012)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2 • AA-O1-DT3	• AA-O1-P1
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT3 • AA-O5-DT4 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2
5	University of Phoenix (Pirani & Albrecht, 2005)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2 • AA-O1-DT3 • AA-O1-DT4	• AA-O1-P1 • AA-O1-P3
		O2. Infrastructure management	• AA-O2-DT1	• AA-O2-P1 • AA-O2-P2
		O3. Faculty management	• AA-O3-DT2	• AA-O3-P1 • AA-O3-P2
		O4. Financial management	• AA-O4-DT1 • AA-O4-DT2 • AA-O4-DT3 • AA-O4-DT4	• AA-O4-P1 • AA-O4-P2
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT3 • AA-O5-DT4 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2 • AA-O5-P3 • AA-O5-P4
6	MAP-works (Woosley & Jones, 2011)	O1. Student Management	• AA-O1-DT1 • AA-O1-DT2 • AA-O1-DT3	• AA-O1-P1
		O3. Faculty management	• AA-O3-DT2	• AA-O3-P1
		O4. Financial management	• AA-O4-DT1	–
		O5. Student retention	• AA-O5-DT1 • AA-O5-DT2 • AA-O5-DT3 • AA-O5-DT4 • AA-O5-DT5	• AA-O5-P1 • AA-O5-P2 • AA-O5-P4

(continued)

Table 6.2 (continued)

#	AA system	AA objective addressed	AA data type harvested	AA purpose targeted
7	Library Cube (Cox & Jantti, 2012)	O1. Student Management	• AA-O1-DT1	• AA-O1-P1
		O2. Infrastructure management	• AA-O2-DT1	• AA-O2-P1
			• AA-O2-DT2	• AA-O2-P2
		O5. Student retention	• AA-O5-DT1	• AA-O5-P4
			• AA-O5-DT3	

[a]Course Signals was initially deployed as an AA tool, however it has been further developed to include LA aspects as well (Gašević et al., 2015). In this table, only the AA deployment is considered

teaching practice (Bach, 2010; Chatti et al., 2012; Clow, 2013a; Diaz & Brown, 2012; Duval & Verbert, 2012; Gibson & de Freitas, 2015; Ifenthaler, 2015). Moreover, unlike Academic Analytics, the contribution of LA on a macro layer is limited.

Learning Analytics do not take a specific educational level standpoint, i.e., it is applied to educational institutions at various levels, such as K-12 schools or HEIs (Davenport, Harris, & Morison, 2010; Elias, 2011; Johnson, Adams Becker, Estrada, & Freeman, 2014; van Barneveld et al., 2012), as well as, in the context of Massive Open Online Courses (MOOCs) towards addressing their "massive" nature and the resulting barriers in terms of learning process orchestration (Clow, 2013b; Coffrin, Corrin, de Barba, & Kennedy, 2014).

2.2.2 Learning Analytics methods and objectives

As aforementioned, Learning Analytics are focused at monitoring and improving the microlayer processes of the educational institutions.[1] In order to address this goal, a significant range of analytical methods has been employed, since the spectrum of educational data that can be extracted and processed is very wide (Ifenthaler & Widanapathirana, 2014). More specifically, the main analytical methods include data mining, statistical methods (e.g., regression and correlation analysis), classification rules, clustering, social network analysis, and visualization methods (Chatti et al., 2012; Clow, 2013a; Papamitsiou & Economides, 2014).

Each of the above methods is utilized towards addressing specific Learning Analytics objectives. Despite the fact that these objectives can vary, depending on the needs of the relevant stakeholders and context of application, a set of common LA objectives consist of (Almosallam & Ouertani, 2014; Chatti et al., 2014; Verbert, Manouselis, Drachsler, & Duval, 2012):

- **LA-O1. Student modeling:** This objective is considered vital for effective decision support at the micro/meso layer. This objective is important both independently (e.g., for student data management) as well as a baseline for achieving the rest of the Learning Analytics objectives (Baker & Inventado, 2014; Clow, 2013a; Dawson & Siemens, 2014; Peña-Ayala, 2014; Siemens & Baker, 2012).

- *Common data types* utilized are
  - Students' personal inherent traits, e.g., demographics and learning style (Chrysafiadi & Virvou, 2013)
  - Students' competence traits, e.g., level of knowledge and skills (Peña-Ayala, 2014)
  - Students' motivation traits (Chrysafiadi & Virvou, 2013)
  - Students' behavioral and emotional patterns (Moridis & Economides, 2009; Pardos, Baker, San Pedro, Gowda, & Gowda, 2013; Verbert, Manouselis, Drachsler, et al., 2012)

[1] In terms of improving teaching practices, an emerging field that has been proposed is Teaching and Learning Analytics (Sergis & Sampson, 2016c), which refers to the process of data-driven reflective teaching practice, based on evidence collected from students' performance indicators using learning analytics methods and tools.

– A combination of the above (Giesbers, Rienties, Tempelaar, & Gijselaers, 2013; Lykourentzou, Giannoukos, Nikolopoulos, Mpardis, & Loumos, 2009).

Given the extensive range of data types that have been reported as potentially useful for addressing this Learning Analytics objective, the set of analysis methods that has been deployed to exploit them is also significant. More specifically, common methods include social network analysis (Buckingham Shum & Ferguson, 2012), predictive modeling (Clow, 2013a), as well as visualization tools for meaningfully depicting the above data and facilitating decision-making (Ali, Hatala, Gašević, & Jovanović, 2012; Gašević et al., 2015).

- *Main Purpose:* The key purposes of this LA objective includes the capacity to create student grouping based on customizable criteria e.g., demographics or level of participation (Dyckhoff, Lukarov, Muslim, Chatti, & Schroeder, 2013). Additionally, profiling students can assist in an overarching manner in order to feed the rest of Learning Analytics objectives e.g., personalized educational resource recommendations based on students' learning styles (Drachsler, Verbert, Santos, & Manouselis, 2015).
- **LA-O2. Educational resources recommendation:** This objective aims to identify and recommend appropriate educational resources to both students and teachers (Bienkowski, Feng, & Means, 2012; Chatti et al., 2014; Papamitsiou & Economides, 2014; Siemens, 2013).
- *Common data types* utilized are
- Regarding students, LA approaches can utilize:

  – Students' models, mentioned in LA-O1 (Drachsler et al., 2015)
  – Students' quantity and type of interaction with educational resources (Drachsler et al., 2015; Dyckhoff, Zielke, Bültmann, Chatti, & Schroeder, 2012)
  – Assessment results (Huang & Fang, 2013; Smith et al., 2012).

Regarding teachers, LA approaches can utilize:

– Teachers' demographics (Bozo, Alarcón, & Iribarra, 2010; Verbert et al., 2012),
– Teachers' competence profile (Sergis, Zervas, & Sampson, 2014c),
– Teachers' social connections to peers (in digital repositories) (Fazeli, Drachsler, Brouns, & Sloep, 2014),
– Teachers' level and type of interaction with educational resources (in digital repositories) (Sergis & Sampson, 2016b; Zapata, Menéndez, Prieto, & Romero, 2013).

Towards harvesting and exploiting these data types, extensive analysis methods have been employed, usually in combination with each other, including user and task classification, user clustering, user modeling, and profiling and rule-based recommendations (Drachsler et al., 2015).

- *Main Purpose:* Regarding students, this Learning Analytics objective commonly focuses on:

  – Identifying appropriate educational resources to support and scaffold learning in a personalized manner, e.g., by adhering to the learning style of the student (Manouselis, Drachsler, Vuorikari, Hummel, & Koper, 2011; Verbert, Manouselis, Drachsler, et al., 2012) and
  – Identifying specific competence gaps through personalized recommendation of assessment resources (Barla et al., 2010; Drachsler et al., 2015).

  - Recommending educational pathways based on their prior performance and course selections (Almosallam & Ouertani, 2014; Bienkowski et al., 2012).

Regarding teachers, this Learning Analytics objective commonly focuses on:

- Recommendation of educational resources for educational scenario design and delivery (Manouselis, Drachsler, Verbert, & Duval, 2013; Sergis et al., 2014c; Sergis & Sampson, 2014b; Sergis, Zervas, & Sampson, 2014a) and
- Recommendation of peers in communities of practice in order to promote professional development (Rafaeli, Barak, Dan-Gur, & Toch, 2004).

- **LA-O3. Student assessment and performance feedback provision:** This objective relates to (a) the facilitation of the student in gaining a high level of self-awareness on their performance and progress, (b) the facilitation of the teacher to deploy effective assessment activities and feedback on demand, and (c) the identification of students "at-risk" in terms of low performance (Macfadyen, Dawson, Pardo, & Gasevic, 2014; Papamitsiou & Economides, 2014; Tempelaar, Heck, Cuypers, van der Kooij, & van de Vrie, 2013).
- *Common data types* utilized are

  - Students' level of engagement and performance in the learning process (Arnold & Pistilli, 2012; Giesbers et al., 2013),
  - Students' quantity and type of interaction with educational resources (Ali et al., 2012; Dietz-Uhler & Hurn, 2013),
  - Behavioral and emotional patterns (Pardos et al., 2013; Verbert, Manouselis, Drachsler, et al., 2012)
  - Students' assessment results (Bienkowski et al., 2012)
  - Analysis of students' social contributions and collaborations (Baker & Siemens, 2015; Buckingham Shum & Ferguson, 2012; Dawson, Bakharia, & Heathcote, 2010; Fessakis, Dimitracopoulou, & Palaiodimos, 2013), as well as
  - A combination of the above (Dimopoulos, Petropoulou, & Retalis, 2013).

The analysis methods employed for this objective are very similar to those exploited for the LA-O1 objective, i.e., student assessment and feedback provision is strongly based on student profiles.

- *Main Purpose:* Providing timely and detailed feedback and facilitating assessment activities is considered a significant factor for enhanced personalized learning experiences (Papamitsiou & Economides, 2014). More specifically, it can aid in the:

  - Assessment of students based on a variant set of performance criteria (Tempelaar et al., 2013),
  - Identification of students' performance trends (Greller & Drachsler, 2012),
  - Provision of insights to the teacher for personalized tutoring/scaffolds to students towards enhanced academic performance, motivation, and engagement (Ali et al., 2012; Arnold & Pistilli, 2012; Chatti et al., 2014; Clow, 2013a; Greller & Drachsler, 2012),
  - Stimulation of students' sense of self-regulated progress via direct feedback using visualizations and alerts (Clow, 2013a, 2013b; Verbert, Duval, Klerkx, Govaerts, & Santos, 2013; Verbert, Manouselis, Drachsler, et al., 2012),

  - Monitoring of students' competence development in relation to the curriculum objectives (Howlin & Lynch, 2014; Larusson & White, 2012).

These insights can facilitate leaders and teachers to increase the level of students' retention and performance through early warning alerts (Almosallam & Ouertani, 2014; Baker & Siemens, 2015; de Freitas et al., 2014; Dyckhoff et al., 2012; Gašević et al., 2015; Romero-Zaldivar, Pardo, Burgos, & Kloos, 2012). The latter, apart from the evident benefit of improving the students' outcomes, has also great potential for facilitating the leadership to meet internal and external accountability mandates related to student success (Dietz-Uhler & Hurn, 2013; Macfadyen et al., 2014). Moreover, a significant benefit that Learning Analytics can deliver in terms of assessing and providing feedback to students is their capacity to be deployed in large scale, by automating (partly or fully) the related tasks (Buckingham Shum, 2012; Coffrin et al., 2014). The latter is becoming increasingly important considering the rise of Massive Open Online Courses and the resulting need for providing efficient assessment methods for massively evaluating student performance and engagement (Clow, 2013b; Gašević, Kovanović, Joksimović, & Siemens, 2014; Kizilcec, Piech, & Schneider, 2013).

- **LA-O4. Teacher feedback provision:** This objective primarily relates to the provision of actionable insights to teachers towards performing evaluations and adaptations to the teaching strategies they have utilized (Gunn, 2014). The reflective adaptations could be provided and utilized either on-the-fly or in a summative manner. On-the-fly adaptations are commonly performed during the delivery of the teaching practice, whereas summative adaptations are commonly performed after the finalization of the delivery phase of the teaching practice, in subsequent runs.

- *Common data types* utilized are
  - Students' level of engagement and/or performance in learning activities (Ali et al., 2012)
  - Analysis of students' social contributions and collaborations (Buckingham Shum & Ferguson, 2012; Dawson et al., 2010),
  - Students' quantity and type of interaction with educational resources (Dyckhoff et al., 2012)
  - Consolidated resource usage level from all and/or groups of students (Zhang, Almeroth, Knight, Bulger, & Mayer, 2007)
  - Results from different types of formative and summative assessment activities (Almosallam & Ouertani, 2014; Bach, 2010; Chatti et al., 2012)
  - Teachers' level and type of interaction and communication with students (Dawson et al., 2010)

Harvesting these data requires analysis methods including social network analysis, e.g., for overseeing the students' level of participation and engagement (Buckingham Shum & Ferguson, 2012; Dawson et al., 2010), clustering methods, e.g., for formulating groups of students based on their level of academic performance and participation (Scheuer & Zinn, 2007), as well as visualization methods for making sense of the data types and highlighting important issues (Verbert et al., 2013).

- *Main Purpose:* The analysis of the above data can lead to insights related to:
  - Facilitation of teachers to critically analyze their educational design (and/or, the overall curriculum) and to identify specific aspects which proved problematic (Bach, 2010). Examples of such insights include identification of educational resources receiving a low level of interaction by the students (Dyckhoff et al., 2012), learning activities which did not sufficiently engage students (Monroy, Rangel, & Whitaker, 2014) and areas of the educational design which proved difficult to the students (Howlin & Lynch, 2014).
  - Performance benchmarking between peer teachers (Dyckhoff et al., 2013).

Table 6.3 provides a consolidated overview of the above analysis of LA objectives, towards:

- Supporting Sect. 2.1.3, which presents an analysis of an indicative examples of existing Learning Analytics systems. The purpose of this analysis is to identify the level of accommodation that these systems' functionalities provide in terms of each Learning Analytics objective and identify potential shortcomings,
- Providing a basis for formulating the proposed School Analytics framework (Sect. 3) by highlighting the objectives of Learning Analytics which could be useful for supporting the micro/meso layer K-12 school leadership tasks.

2.2.3 Learning Analytics systems

Table 6.4 presents the analysis of an indicative sample of nine existing Learning Analytics systems, in terms of the level of accommodation that these systems' functionalities offer for each Learning Analytics objective's purposes. These Learning Analytics systems were selected due to the fact that they have been reported as significant milestones in the Learning Analytics research agenda (Dyckhoff et al., 2013).

As Table 6.4 depicts, all of the LA objectives are being accommodated by the indicative sample of LA systems. The core focus appears to be placed on the objectives "*LA-O1. Student modeling*", "*LA-O3. Student assessment and performance feedback provision*" and "*LA–O4. Teacher feedback provision*". However, the objective "*LA-O2. Educational resources recommendation*" has also received a significant level of research attention, but it has been performed mainly in an isolated research area, which is increasingly being fused to Learning Analytics (Chatti et al., 2012; Greller & Drachsler, 2012; Verbert, Manouselis, Drachsler, et al., 2012).

Two significant insights can be drawn based on the above analysis:

- A limited level of accommodation was identified in terms of supporting profiling and activity logging for the *teachers*. Teachers have received much less attention towards effective profiling and activity tracking compared to students (Dyckhoff et al., 2013; Sergis et al., 2014a; Sergis & Sampson, 2014b). This general lack of efficient teacher data harvesting and exploiting (e.g., competences) is a significant shortcoming which limits the leadership capacity to have a transparent view of the micro layer, and especially the meso layer.

Table 6.3 Overview of Learning Analytics objectives and related elements

LA objective	Common data types utilized	Main purposes	Role involved
O1. Student modeling	• **LA-O1-DT1**. Students' demographics/inherent traits	• **LA -O1-P1.** Student grouping based on customizable criteria	Leader
	• **LA-O1-DT2.** Students' competence traits		Teacher
	• **LA-O1-DT3.** Students' motivation traits		Student
	• **LA-O1-DT4.** Students' behavioral/ emotional patterns		
O2. Educational resources recommen dation	• **LA–O2-DT1**. Students' demographics/inherent traits	• **LA-O2-P1**. Recommend personalized scaffolding educational resources	Student Teacher
	• **LA–O2-DT2.** Students' competence traits	• **LA-O2-P2**. Recommend personalized assessment educational resources	
	• **LA–O2-DT3**. Students' motivation traits	• **LA-O2-P3**. Recommend personalized educational pathways	
	• **LA–O2-DT4**. Students' behavioral/ emotional patterns		
	• **LA–O2-DT5**. Students' quantity and type of interaction with educational resources		
	• **LA–O2-DT6**. Students' assessment results		
	• **LA–O2-DT7**. Teachers' demographics	• **LA-O2-P4**. Recommend personalized educational resources for educational scenario design and delivery	
	• **LA–O2-DT8**. Teachers' competence profile	• **LA-O2-P5**. Recommend peers for community of practice formulation	
	• **LA–O2-DT9**. Teachers' social connection with peers.		
	• **LA–O2-DT10**. Teachers' quantity and type of interaction with educational resources		

(continued)

Table 6.3 (continued)

LA objective	Common data types utilized	Main purposes	Role involved
O3. Student assessment and performance feedback provision	• **LA-O3-DT1**. Students' level of engagement/performance in learning activities	• **LA–O3-P1**. Assess students based on variant set of performance criteria	Teacher Student
	• **LA–O3-DT2**. Students' quantity and type of interaction with educational resources	• **LA–O3-P2**. Identification of students' performance trends	
	• **LA-O3-DT3**. Students' behavioral/ emotional patterns	• **LA–O3-P3**. Recommend personalized tutoring/ scaffolds to students	
	• **LA–O3-DT4**. Students' assessment results	• **LA–O3-P4**. Promote students' self-regulation through direct feedback	
	• **LA–O3-DT5**. Analysis of students' social contributions and collaborations	• **LA–O3-P5.** Monitor students' competence development	
O4. Teacher feedback provision	• **LA-O4-DT1**. Students' level of engagement/performance in learning activities	• **LA-O4-P1**. Targeted reflection and adaptations on learning design	Teacher
	• **LA–O4-DT2**. Analysis of students' social contributions and collaborations	• **LA-O4-P2.** Performance benchmarking with peer teachers	
	• **LA–O4-DT3**. Students' quantity and type of interaction with educational resources		
	• **LA–O4-DT4**. Consolidated resource usage level		
	• **LA–O4-DT5**. Student assessment results		
	• **LA–O4-DT6**. Teachers' quantity and type of interaction and communication with students		

Table 6.4 Overview of Indicative Sample of Learning Analytics Systems

#	LA system	LA objective addressed	LA data type harvested		LA purpose targeted
1	LAE-R (Petropoulou, Kasimatis, Dimopoulos, & Retalis, 2014)	O1. Student modeling	• LA-O1-DT1		• LA -O1-P1
			• LA-O1-DT2		
		O3. Student assessment and performance feedback provision	• LA-O3-DT1	• LA–O3-DT4	• LA–O3-P1
			• LA–O3-DT2	• LA–O3-DT5	• LA–O3-P5
			• LA-O3-DT3		
		O4. Teacher feedback provision	• LA-O4-DT1	• LA–O4-DT4	• LA-O4-P1
			• LA–O4-DT2	• LA–O4-DT5	
			• LA–O4-DT3		
2	LOCO-Analyst (Ali et al., 2012)	O1. Student modeling	• LA-O1-DT1	• LA-O1-DT4	• LA -O1-P1
			• LA-O1-DT2		
		O3. Student assessment and performance feedback provision	• LA-O3-DT1	• LA–O3-DT4	• LA–O3-P1
			• LA–O3-DT2	• LA–O3-DT5	• LA–O3-P4
			• LA-O3-DT3		• LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1	• LA–O4-DT4	• LA-O4-P1
			• LA–O4-DT2	• LA–O4-DT5	
			• LA–O4-DT3		

3	SNAPP (Dawson et al., 2010)	O1. Student modeling	• LA-O1-DT4		• LA -O1-P1
		O3. Student assessment and performance feedback provision	• LA-O3-DT1 • LA-O3-DT3	• LA–O3-DT5	• LA–O3-P1
		O4. Teacher feedback provision	• LA-O4-DT1 • LA–O4-DT2	• LA–O4-DT6	• LA-O4-P1
4	eLAT (Dyckhoff et al., 2012)	O1. Student modeling	• LA-O1-DT1 • LA-O1-DT2	• LA-O1-DT3 • LA-O1-DT4	• LA -O1-P1
		O3. Student assessment and performance feedback provision	• LA-O3-DT1 • LA–O3-DT2	• LA-O3-DT3 • LA–O3-DT4	• LA–O3-P1 • LA–O3-P4 • LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1 • LA–O4-DT3	• LA–O4-DT4 • LA–O4-DT5	• LA-O4-P1
5	RealizeIT (Howlin & Lynch, 2014)	O1. Student modeling	• LA-O1-DT1 • LA-O1-DT2	• LA-O1-DT4	• LA -O1-P1
		O2. Educational resources recommendation	• LA–O2-DT1 • LA–O2-DT2 –	• LA–O2-DT6	• LA-O2-P3 –
		O3. Student assessment and performance feedback provision	• LA-O3-DT1 • LA-O3-DT3	• LA–O3-DT4 • LA–O3-DT5	• LA–O3-P1 • LA–O3-P2 • LA–O3-P4 • LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1 • LA–O4-DT2	• LA–O4-DT4 • LA–O4-DT5	• LA-O4-P1 • LA-O4-P2

(continued)

Table 6.4 (continued)

#	LA system	LA objective addressed	LA data type harvested		LA purpose targeted
6	MOODOG (Zhang et al., 2007)	O1. Student modeling	• LA-O1-DT1		• LA -O1-P1
			• LA-O1-DT4		
		O3. Student assessment and performance feedback provision	• LA-O3-DT1	• LA–O3-DT4	• LA–O3-P1
			• LA–O3-DT2	• LA–O3-DT5	• LA–O3-P4
			• LA-O3-DT3		• LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1	• LA–O4-DT4	• LA-O4-P1
			• LA–O4-DT2	• LA–O4-DT5	
			• LA–O4-DT3		
7	Student Activity Monitor (Govaerts, Verbert, Klerkx, & Duval, 2010)	O1. Student modeling	• LA-O1-DT1		• LA-O1-P1
			• LA-O1-DT4		
		O2. Educational resources recommendation	• LA–O2-DT4	• LA–O2-DT6	• LA-O2-P1
			• LA–O2-DT5		• LA-O2-P2
			• –		• –
		O3. Student assessment and performance feedback provision	• LA-O3-DT1		• LA–O3-P1
			• LA–O3-DT2		• LA–O3-P2
			• LA–O3-DT4		• LA–O3-P3
					• LA–O3-P4
					• LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1	• LA–O4-DT4	• LA-O4-P1
			• LA–O4-DT2	• LA–O4-DT5	
			• LA–O4-DT3		

8	StepUP (Santos, Verbert, Govaerts, & Duval, 2013)	O1. Student modeling	• LA-O1-DT4		• LA -O1-P1
		O3. Student assessment and performance feedback provision	• LA-O3-DT1	• LA–O3-DT5	• LA–O3-P1
			• LA-O3-DT3		• LA–O3-P4
		O4. Teacher feedback provision	• LA-O4-DT1		• –
			• LA–O4-DT2		
9	Check My Activity (Fritz, 2011)	O1. Student modeling	• LA-O1-DT1	• LA-O1-DT4	• LA -O1-P1
			• LA-O1-DT2		
		O3. Student assessment and performance feedback provision	• LA-O3-DT1	• LA-O3-DT3	• LA–O3-P1
			• LA–O3-DT2	• LA–O3-DT4	• LA–O3-P3
					• LA–O3-P4
					• LA–O3-P5
		O4. Teacher feedback provision	• LA-O4-DT1	• LA–O4-DT5	• LA-O4-P1
			• LA–O4-DT3	• LA–O4-DT6	• LA-O4-P2
			• LA–O4-DT4		

- Extending the above, a limited level of accommodation for capturing data related to micro layer factors, beyond the students, is observed. More specifically, the latter should include a holistic method of capturing and exploiting other micro/meso layer data (such as teaching practices utilized, physical context affordances, teacher competences, etc.) towards meaningfully informing the processes of educational design, delivery, and reflection (Greller & Drachsler, 2012).

2.3 Reflections on Academic Analytics and Learning Analytics

The analyses performed in Sects. 2.1 and 2.2 on Academic Analytics and Learning Analytics respectively have resulted in a set of reflections related to their focal points and objectives. More specifically:

- **Academic Analytics** take a strong standpoint in terms of (a) organizational processes, by explicitly addressing the macro layer of an educational institution functions and (b) educational level, by focusing on HEI. Moreover, despite their highly granulated coverage of the Business Intelligence of the educational institution, there is a lack of adequate overview of the micro/meso layer processes, which is viewed as a "black box" to a large degree (Macfadyen & Dawson, 2010). This fact can hinder the leadership's capacity to take institutional-wide decisions towards improving the educational outcomes of the institution, considering that there is limited consideration to the teaching practices being undertaken and how these are affected by (or affect) the processes of the meso layer.

  In terms of applicability to the K-12 school context, Academic Analytics are not directly applicable (given their explicit HEI focus), however, their data types could provide a basis for informing relevant analytics approaches for addressing the macro layer school leadership tasks.
- **Learning Analytics**, on the other hand, are primarily concerned with the micro and meso layers, towards assisting teachers and students in enhancing the effectiveness of the teaching and learning process (Arnold et al., 2014). However, existing Learning Analytics approaches cannot adequately support the macro layer decision-making processes, since they do not incorporate Business Intelligence.

  In terms of applicability to the K-12 school context, Learning Analytics are directly applicable (Piety, Hickey, & Bishop, 2014), but, as aforementioned, have a limited institutional layer coverage.

The above reflections suggest that there is no existing unifying approach towards providing support for holistic and complexity leadership in educational institutions, even more so when the context of study is narrowed down to K-12 schools. This conclusion is based on the fact that K-12 school leaders have been assigned with a complex set of tasks spanning from the highly granulated overview of the micro layer processes, the orchestration of the meso layer, to the engagement in the operational tasks of the macro layer (Bush & Glover, 2014;

OECD, 2013). Moreover, school leaders require *systemic* decision-making support, which will not only harvest the aforementioned data, but will also analyze them in an intertwining manner towards providing feedback loops on the performance of the diverse agents of the school system and will, therefore, generate insights for school-wide action planning based on the current level of the system emergence (Coburn & Turner, 2011). However, the required *systemic* decision-making support and data collection channels are not provided by either the existing AA or LA approaches, in isolation.

Under the light of the above, a need is identified for an analytics framework that will be targeted specifically at accommodating the needs of Complexity Leadership of K-12 school leaders, in terms of the required institution-wide data collection and exploitation for providing detailed feedback loops. The concept of *School Analytics* (SA) is, therefore, proposed and presented in the following section, along with the key principles of School Complexity Leadership. The focal points and objectives of School Analytics are based on (a) the core tasks of school leaders as they have been described in previous work in the form of a core School Leadership Tasks framework (SLT) (Sergis & Sampson, 2016a) and (b) the analysis of existing Academic Analytics and Learning Analytics objectives and their capacity to support the complexity K-12 school leadership by providing granulated feedback loops which can allow the leaders to influence the state of their school's emergence towards meeting their strategic plans.

3 School Analytics: Supporting School Complexity Leadership

3.1 School Complexity Leadership: Concept and Core Tasks

Complex Adaptive Systems (CAS) within the context of complexity theory are systems comprising a wide range of agents which co-exist, interplay, and constantly evolve at different layers of the System, influenced by the actions of other agents towards achieving optimal fitness within the System as a whole (Hmelo-Silver & Azevedo, 2006; Huang & Kapur, 2012; Wallis, 2008). This vast web of interconnections and interactions between the involved agents produce data that can affect the actions of the agents by generating constant *feedback loops* to these agents (Holland, 1998; Trombly, 2014). Furthermore, these feedback loops and the collective behaviors of the agents result in the formulation of the System *status* in a process known as emergence (Holland, 1998; Lichtenstein et al., 2006; Miller & Page, 2007). The basic notion behind *emergence* is that each current status of the system is not a linear sum of its constituent parts but has been forged in a networked and unpredictable manner by the characteristics and interactions of its agents (Uhl-Bien & Marion, 2009).

In this context, Complexity Leadership (CL) is primarily addressed at orchestrating such complex adaptive systems (Schneider & Somers, 2006; Uhl-Bien & Marion, 2009). This approach allows for a different standpoint for leadership, where strategic planning and outcomes are not solely devised by a single agent (*administrative leadership*), but are also the result of an unpredictable range of actions and interactions (*adaptive leadership*) (Lichtenstein et al., 2006; Uhl-Bien et al., 2007). The notion of adaptive leadership is related to the concept of distributed leadership and posits the notion that leadership should not be entirely "top–down" or "bottom–up" oriented, since both these approaches present issues related to the adoption and exploitation of the leadership decisions (Huang & Kapur, 2007; Uhl-Bien et al., 2007).

Furthermore, a key aspect of CL is related to enabling and sustaining a constant *flow of data and inter-agent interactions*, which are required for generating feedback loops and, ultimately, system emergence (Uhl-Bien et al., 2007; Uhl-Bien & Marion, 2009). Thus, it is commonly acknowledged that leadership efforts should be placed on mechanisms for capturing, collecting, modeling, and analyzing these interactions and their related, institution-wide data (Lichtenstein et al., 2006)

Schools have been repeatedly regarded as (social) CAS, due to the fact that they comprise the aforementioned core characteristics of CAS (Keshavarz, Nutbeam, Rowling, & Khavarpour, 2010; Snyder, 2013; Trombly, 2014). More specifically, they comprise a wide ecosystem of interrelated agents (e.g., teachers, leaders, students, parents, official accountability, infrastructural aspects), whose interactions and characteristics are combined into collective organizational system outcomes (Mital, Moore, & Llewellyn, 2014).

In this context, Complexity Leadership could also be applied for studying School Leadership in particular (Axelrod & Cohen, 2000; Morrison, 2010). School Complexity Leadership (following the principles of general CL) mainly comprises the *administrative* and the *adaptive* strands. The former is related to the strictly "top–down" leadership processes, focusing on the managerial aspects of leading an organization (Uhl-Bien et al., 2007). Examples of administrative school leadership, which is usually performed by the principal leader, are strategic planning for the organization, allocation of resources, and coordinating activities (OECD, 2013). The adaptive school complexity leadership strand, which is closely related to the distributed leadership standpoint, posits that leadership needs to be shared within a "top–down" and a "bottom–up" approach, in order to be effective (OECD, 2013). More specifically, it refers to the adaptive and fluid interactions of the system agents (a key strand of which are the teacher leaders) that emerge from practice and not strictly as a result of authority.

It is becoming increasingly evident that effective and holistic school organizational development views both these leadership strands (administrative and adaptive) as complementary (Bush & Glover, 2014; OECD, 2008, 2013). In order to allow for this complementarity, school complexity leadership is heavily reliant on formulating, sustaining, and exploiting institution-wide mechanisms for collecting educational data among the agents of each organizational layer (Morrison, 2010). More specifically, collection of such data and agent interactions from an institution-wide perspective accommodates the need for and generates feedback loops for the current state of the school (e.g., student outcomes, teacher actions, parents' requirements, official accountability reports and policies). These feedback loops, as aforementioned, directly impact the actions of the system agents (which respond and adapt to this information) and re-shape the School System to new states of emergence (Hmelo-Silver & Azevedo, 2006). Thus, they should be captured and exploited towards (partly) “influencing” these states of emergence (mainly by the principal and teacher leaders) and aligning them to the intended school organizational strategic plans (McQuillan, 2008).

Based on the above, this book chapter adopts the complexity strand of school leadership and will focus on two core leadership agents, i.e., the principal leader strand and the teacher leader strand, in terms of their actions within the school social CAS towards “influencing” the states of school emergence (Crowther, Ferguson, & Hann, 2009; Leithwood et al., 2007; OECD, 2008, 2013). In our previous work, a core School Leadership Task Framework (SLT) was proposed towards providing a means of modeling the core school leadership tasks (Sergis & Sampson, 2016a). Within the context of complexity leadership, the proposed SLT attempts to capture the core aspects of school functions which are affected by administrative leadership, but also nurture the emergent adaptive leadership. More specifically, the formulated SLT Framework describes commonly recognized aspects of school function that are orchestrated by the school leadership team and include a wider range of school system agents (e.g., parents, teachers, external accountability bodies and the students). The identified school leadership tasks are mainly related to capturing and monitoring these aspects towards receiving constant flow of feedback loops and evaluating the states of emergence of the school organization. The proposed SLT highlighted a set of eleven such tasks, which are depicted in Table 6.5.

The above SLT is utilized in this book chapter as a backbone for driving the formulation of the proposed School Analytics framework, namely by providing a means to map the objectives of existing Academic Analytics and Learning Analytics approaches, towards supporting the provision of more granulated feedback loops that will inform the identified core school complexity leadership tasks. This process is described in the following section, following an introduction to the concept of School Analytics.

3.2 School Analytics

3.2.1 School Analytics Definition

As aforementioned, school complexity leadership is a process that requires decision-making at all institutional layers of the schools, based on a diverse set of data towards gaining insights on the diverse interactions of the interrelated agents of the schools. Moreover, as the analyses presented in Sects. 2.1 and 2.2 highlighted, existing LA and AA approaches provide limited decision support capacity for these school leadership tasks, given their individual focal points and objectives. School Analytics (SA) aim to address this shortcoming, by directly supporting the

Table 6.5 Core School Leadership Tasks (adapted from Sergis & Sampson, 2016a)

Core School Leadership Task	Brief description of feedback loop focus	Institutional layer
Learning process monitoring	This task relates to the monitoring of the learning processes that occur at the micro layer. Data types related to this leadership task can include (a) types of instructional practices and processes delivered and (b) (quantity and) method of utilized learning resources and tools	Micro
Learning process evaluation	This task relates to the utilization of the data from the "Learning process monitoring (T1)" and their analysis towards remedying actions for improvement of the teaching and learning processes of the school. For example, this can include an evaluation of the efficiency of the adopted instructional practices (and/or learning resources and tools) using the learners' academic performance, feedback, and level of participation/ engagement as a benchmark. A low level of the latter can assist school leaders to identify specific aspects of the teaching practice which were ineffective	
Learner performance monitoring	This task relates to the disaggregated (for the micro layer), as well as aggregated (for the meso and/or macro layer) data related to the learners' academic performance. These data can include among others, behavioral issues of the learners, absenteeism rates, level of participation within the learning activities, and level/type of interactions with the teacher/leader/parents	
Learner performance evaluation	This task mainly relates to the assessment of the learners' academic performance based on the data collected from monitoring their progress and actions during the learning process (both within and beyond the physical premises of the school). This evaluation could be diagnostic, formative, and/or summative and generate corresponding feedback loops	

Curriculum planning	This task relates to the identification of issues related to the existing curriculum and the actions towards remedy. These issues are mainly elicited from the feedback loops of the previous tasks and can relate either to shortcomings identified at a micro layer (e.g., general difficulty of learners to cope with a specific curriculum section) or to externally imposed mandates (e.g., new subject domain standards).	Meso
Teaching staff management	This task relates to the monitoring and management of the teaching staff of the school in terms of both teaching performance (e.g., through the monitoring of the teaching processes and the related competences of the teachers) as well as operations (e.g., attendance, demographics, and payroll	
Teaching staff professional development	This task relates to the identification of potential shortcomings in the teaching staff's competences and the organization and promotion of appropriate professional development opportunities to alleviate. Moreover, it can refer to the tasks of selecting and recruiting of new teaching staff, more appropriate for the School System needs	
District stakeholder accountability	This task relates to formulating and sustaining communication channels with interested stakeholders of the school in order to allow for capturing their own feedback loops towards capturing the level in which they affect the school System's level of emergence. Examples of such two-way feedback loops can include retention rate reports and financial reports of the school addressed at the policy makers, policy mandates from the policy makers to the school, as well as continuous two-way communication and collaboration between the teachers, students, and the parents of the latter	
Infrastructural resource management	This task relates to the monitoring and management (e.g., monitor, maintenance, procurement) of the infrastructural assets of the school, such as hardware and software equipment	
Financial resource management	This task relates to the monitoring and orchestration of the financial aspects of the school, such as budget formulation, accounting tasks, and external funding	
Learner data management	This task relates to the overall management of learners' data, such as demographics, tuition fees, and prior academic background. Apart from the strictly administrative need for record keeping, such data types (which, like staff management, are related to the characteristics of a set of System's agents) can be exploited as a means to explain the interactions of these agents with the rest of the System. Therefore, this information can facilitate in the (at least partial) understanding of the current level of System emergence	

identified tasks of school leaders, as well as providing the means for cultivating and exploiting intra-layer communication and information channels of the school, necessary for nurturing both administrative as well as adaptive leadership.

Moreover, the proposed School Analytics should aim to move beyond harvesting these institutional-wide data, towards a more systemic standpoint. This should include data collection at all layers and, furthermore, identification of co-relations and interdependencies between them, again on all institutional layers, for the generation of feedback loops that could inform the strategic plans of the leadership team towards aligning the emergence state of the institution to the aforementioned strategic plans.

Overall, the SA framework is built in a bottom–up approach, sprouting from the SLT and by mapping and extending existing analytics standpoints, utilizing the SLT as a foundational basis and benchmark. The following section presents the SA framework and highlights two core implications it can deliver to systemic school leadership.

3.2.2 School Analytics Objectives and Data Types

Table 6.6 presents the mapping between the SLT framework and the existing LA and AA objectives. This process aims to provide the basis of the proposed SA approach, by highlighting (a) the data types and purposes to be utilized, as well as (b) the manner in which these are connected at all organizational layers.

The first implication of the proposed SA framework is directly observable from Table 6.6 and relates to the re-distribution of *existing* data types and purposes of LA and AA approaches, over the diverse SLT element grid. More specifically, this re-distribution highlights the need to utilize institutional data types to achieve purposes beyond their initial harvesting layer. For example, curriculum planning (currently at the meso layer) should be informed by a highly detailed depiction of the processes occurring at the micro layer. This depiction should not only span the final student learning outcomes, but also incorporate elements such as the student and teacher level of engagement, the quantity and type of interactions with educational resources, the students' parents (e.g., their level of involvement) as well as the detailed competence building progress of students. This could allow for more targeted reflections (feedback loops) for the leadership team and remedying actions to improve specific aspects of the curriculum, based on data-driven insights.

The second implication of the proposed SA framework aims to propose *extensions* of the existing analytics approaches. These extensions, which are also informed by the shortcomings of existing LA and/or AA systems highlighted in Sects. 2.1.3 and 2.2.3, mainly relate to advancing the SA purposes for facilitating school complexity leadership by enhancing the communication and information channels of the school, necessary for nurturing both *administrative* as well as *adaptive leadership*.

- **Transparent learning process monitoring/Learning process evaluation/ Curriculum planning:** School Analytics posits the standpoint that there is need for *holistic* exploitation of institutional data towards effective monitoring and evaluation of the learning (and teaching) processes of the micro layer, as well as the curriculum planning processes of the meso layer.

This standpoint, however, requires solid foundations in terms of the involved factors' data. As aforementioned in Sect. 2.2.3, however, not all of these factors are adequately being profiled. For example, teachers have received very little research attention in terms of profiling, in contrast to students (Dyckhoff et al., 2013; Sergis et al., 2014a). This is a significant shortcoming, since the profile of the teacher (e.g., in terms of competences) can greatly affect the organizational development of the school especially in terms of the use of ICT in the teaching process (European Commission, 2013). Therefore, SA opts to incorporate detailed profiling mechanisms for teachers (e.g., Bozo et al., 2010; Fazeli et al., 2014; Sergis & Sampson, 2014b; Zapata et al., 2013), and utilize these data towards providing a more transparent view of the micro/meso layer processes. Moreover, explicit profiling of other factors involved in the micro/meso layer processes is also required e.g., the specific teaching method utilized, as well as the full range of the school's physical and digital infrastructure being exploited.

SA, therefore, argues that having these detailed data on the micro/meso layer processes can unlock the potential for highly granulated evaluations, by correlating the students' level of engagement and final outcomes to the factors that directly affect it. These data-driven monitoring and evaluation processes could enable targeted reflections and adaptations, both on-the-fly, as well as in a summative manner.

- **Redefining "best" teaching practice:** Additionally to the above SA implication, these highly profiled and robustly evaluated teaching practices could be shared amongst web-based teaching communities, towards the formulation of "conditional best teaching practice" pools. These pools of teaching practices will be available to be selected as "best" for re-use by other interested teachers in a conditional manner, i.e., by considering not only the final student outcomes, but also the context in which these student outcomes were achieved. Therefore, each teacher will be able to receive recommendations based on the compatibility of each "best" practice in terms of their own school context, and make more informed selections.
- **Recommendations for targeted teacher professional development:** Another implication of SA building on the need for refining teacher competence profiling mechanisms, relates to the provision of recommendations for targeted professional development opportunities addressed to individual teachers. More specifically, teachers highlighted with a low level of certain competences should be facilitated in identifying specific professional development opportunities tackling their individual shortcomings (Sergis, Zervas, & Sampson, 2014b).
- **Targeted recruitment of teachers:** School principal leaders could also utilize SA in order to receive recommendations on teacher candidates whose competence profile matches their school's related needs. This process could utilize the detailed profiles of the existing teachers and, therefore, the competence-related needs of the school, as well as existing frameworks for targeted teacher recruitment (e.g., Bowles, Hattie, Dinham, Scull, & Clinton, 2014; Sergis et al., 2014b).

Table 6.6 The proposed School Analytics Framework

Institutional layer	SLT element	LA and/or AA purposes		LA and/or AA data types	
Micro	Learning process monitoring	–		• AA-O1-DT3	• AA-O3-DT3
				• AA-O2-DT2	• AA-O5-DT4
		• LA-O2-P4	• LA-O4-P1	• LA–O2-DT4/LA-O3-DT3	• LA–O3-DT2/LA–O4-DT3
		• LA–O3-P2		• LA–O2-DT5	• LA–O3-DT5/LA–O4-DT2
				• LA–O2-DT8	• LA–O4-DT4
				• LA–O2-DT10	• LA–O4-DT6
				• LA-O3-DT1/LA-O4-DT1	
	Learning process evaluation	• AA-O3-P2		• AA-O2-DT2	• AA-O5-DT4
		• AA-O5-P4		• AA-O5-DT3	
		• LA-O1-P1	• LA-O4-P2	• LA-O1-DT4/LA–O2-DT4/ LA-O3-DT3	• LA–O3-DT4
		• LA–O3-P5		• LA–O2-DT5/LA–O3-DT2LA–O2-DT6/LA–O4-DT5	• LA–O3-DT5/LA–O4-DT2
		• LA-O4-P1		• LA–O2-DT10	• LA–O4-DT4.
				• LA-O3-DT1/LA-O4-DT1	• LA–O4-DT6
	Learner performance monitoring	• AA-O5-P1	• AA-O5-P3	• AA-O1-DT1	• AA-O5-DT4
		• AA-O5-P2		• AA-O1-DT2	• AA-O5-DT5
				• AA-O2-DT2	
		• LA-O2-P1	• LA–O3-P3	• LA-O1-DT4/LA–O2-DT4/LA-O3-DT3	• LA-O3-DT1/LA-O4-DT1
		• LA-O2-P3	• LA–O3-P5	• LA–O2-DT5/LA–O3-DT2/ LA–O4-DT3	• LA–O3-DT5/LA–O4-DT2
		• LA–O3-P2			
	Learner performance evaluation	• AA-O5-P2		• AA-O2-DT2	• AA-O5-DT4
				• AA-O5-DT3	
		• LA-O2-P2	• LA–O3-P3	• LA-O1-DT4/LA-O3-DT3	• LA–O2-DT5/LA–O3-DT2/LA–O4-DT3

		• LA-O2-P3	• LA–O3-P4	• LA-O1-DT2/LA–O2-DT2	• LA–O2-DT6/LA–O3-DT4/LA–O4-DT5
		• LA–O3-P1	• LA–O3-P5	• LA-O1-DT3/LA–O2-DT3	• LA-O3-DT1/LA-O4-DT1
				• LA-O1-DT4/LA–O2-DT4	• LA–O3-DT5/LA–O4-DT2
Mesolayer	Curriculum planning	• AA-O3-P2		• AA-O1-DT3	
		• AA-O5-P4		• AA-O3-DT3	
				• AA-O5-DT3	
				• AA-O5-DT5	
		• LA-O2-P4	• AA-O5-P4	• LA-O1-DT4/LA–O2-DT4	• LA–O2-DT10
		• LA-O4-P1		• LA–O2-DT5/LA–O3-DT2/LA–O4-DT3	• LA-O3-DT1/LA-O4-DT1
				• LA–O2-DT6/LA–O3-DT4/LA–O4-DT5	
	Teaching staff management	• AA-O3-P1		• AA-O3-DT1	• AA-O4-DT2
		• AA-O4-P1		• AA-O3-DT2	• AA-O5-DT3
				• AA-O3-DT3	
		• LA-O2-P4		• LA–O2-DT6/LA–O3-DT4/LA–O4-DT5	• LA–O2-DT10
		• LA-O2-P5		• LA–O2-DT7	• LA-O3-DT1/LA-O4-DT1
		• LA-O4-P2		• LA–O2-DT8	• LA–O4-DT6
				• LA–O2-DT9	
	Teaching staff professional development	• AA-O3-P1		• AA-O3-DT1	
				• AA-O3-DT2	
		• LA-O2-P5		• LA–O2-DT7	• LA–O2-DT10
		• LA-O4-P2		• LA–O2-DT8	• LA–O4-DT6
				• LA–O2-DT9	

(continued)

Table 6.6 (continued)

Institutional layer	SLT element	LA and/or AA purposes		LA and/or AA data types	
	District stakeholder accountability	• AA-O1-P1	• AA-O4-P1	• AA-O1-DT1	• AA-O3-DT3
		• AA-O2-P1	• AA-O4-P3	• AA-O1-DT2	• AA-O4-DT2
		• AA-O3-P1	• AA-O5-P4	• AA-O1-DT3	• AA-O4-DT3
		• AA-O3-P2		• AA-O1-DT4	• AA-O4-DT4
				• AA-O2-DT1	• AA-O5-DT3
				• AA-O3-DT1	
		• LA–O3-P2		• LA-O1-DT2	• LA–O2-DT8
		• LA–O3-P5		• LA-O1-DT3	• LA-O3-DT1/LA-O4-DT1
		• LA-O4-P1		• LA-O1-DT4/LA-O3-DT3	• LA–O4-DT6
		• LA-O4-P2		• LA–O2-DT6/LA–O3-DT4/ LA–O4-DT5	
	Infrastructural resource management	• AA-O2-P1	• AA-O2-P3	• AA-O2-DT1	
		• AA-O2-P2	• AA-O4-P1	• AA-O2-DT2	
		• LA-O2-P1	• LA-O2-P4	• LA–O2-DT5/LA–O3-DT2/ LA–O4-DT3	• LA–O4-DT4
		• LA-O2-P2		• LA–O2-DT10	
	Financial resource management	• AA-O4-P1		• AA-O4-DT1	• AA-O4-DT4
		• AA-O4-P2		• AA-O4-DT2	• AA-O5-DT2
		• AA-O4-P3		• AA-O4-DT3	
	Learner data management	• AA-O1-P1	• AA-O2-P3	• AA-O1-DT1/AA-O5-DT1	• AA-O3-DT3
		• AA-O1-P2	• AA-O4-P1	• AA-O1-DT2	• AA-O4-DT1
		• AA-O1-P3	• AA-O4-P2	• AA-O1-DT3	• AA-O5-DT3
				• AA-O1-DT4/AA-O5-DT2	• AA-O5-DT5
		LA-O1-P1		• LA-O1-DT1/LA–O2-DT1	• LA-O1-DT4/LA–O2-DT4
		LA–O3-P5		• LA-O1-DT2/LA–O2-DT2	• LA–O2-DT6/LA–O3-DT4/LA–O4-DT5
				• LA-O1-DT3/LA–O2-DT3/LA-O3-DT3	

- **Usage-informed infrastructural resource management:** SA argues that the capacity of school leaders to perform this task can be significantly supported beyond the existing approaches, by also considering the micro and meso layer data related to student and teacher exploitation of existing infrastructure. The latter can drive the leader to orchestrate more effectively both available infrastructural resource allocations as well as procurements, given that usage data will be available to highlight needs, trends, as well as the outcomes of each strategic plan.
- **Overarching financial resource management:** Finally, all the above SA implications can have a direct impact on facilitating the school leader to delineate a more focused and accurate financial plan, given that the processes of the school which directly or indirectly affect the financial plan will be more strategically organized and implemented towards "optimal" resource allocation, especially considering the increasingly reduced available financial resources.

As a result of all the above, SA aims to facilitate school leaders to not only drive their school development in a more transparent data-driven manner through the continuous institution-wide feedback loops, but also such data-driven school complexity leadership has the capacity to allow for driving internal school improvement strategic planning as well as for meeting emerging external accountability trends, which posit for qualitative proof of the quality of practices undertaken within schools (Altrichter & Kemethofer, 2015).

4 Conclusion

This chapter introduced the concept of a School Analytics framework, which aims to support the complex tasks of K-12 school leaders, as the latter are described in our previously proposed School Leadership Task framework. The formulation of the School Analytics framework was based on the foundations of school complexity leadership and its essential aspects of feedback loops and emergence. In this context, a critical overview of the two main existing educational analytics strands, namely Learning Analytics and Academic Analytics was performed, focused on the core focal points and objectives that each analytics strand adopts, both conceptually, as well as in terms of systems, by focusing on an indicative sample of "milestone" systems and initiatives. The aim of this overview was to identify whether these Analytics strands can adequately support crucial aspects of school complexity leadership (i.e., continuous feedback loops) in the holistic manner that is required, and to identify specific shortcomings.

The aforementioned analyses pinpointed the shortcomings of the existing analytics strands (individually) to fully accommodate the required holistic needs of K-12 school complexity leadership. More specifically, these limitations were related to (a) the isolated focal point of each analytics strand in terms of data collection and educational context of use and (b) the restrictive confinements imposed in the manner in which the collected data types were being exploited, i.e., with very limited *systemic* exploitation towards overarching organizational improvement.

Taking a step towards addressing these issues, the framework of School Analytics was introduced. School Analytics was built using a bottom–up approach using the School Leadership Task framework as a foundational basis to address the shortcomings of the existing analytics strands. The two core implications of the proposed SA framework relate to (a) meaningfully bridge the existing analytics' objectives towards informing school leadership at all institutional layers through the generation of continuous feedback loops, and (b) extend them in order to eliminate identified shortcomings and enable the provision of decision support recommendations which could facilitate school leaders to capture the current state of emergence of their school and to meaningfully align their strategic plans to it.

Overall, the proposed concept of School Analytics is proposed as a backbone framework for the design of systems which can potentially provide school leaders with the capacity to (a) robustly scan the current level of performance of their school, and (b) have access to robust evidence on the outcomes that it delivers and how can it be adjusted to drive organizational progress. Therefore, future work in this agenda should be aimed at designing, implementing, and evaluating SA systems with the goal of supporting school leaders to navigate their institutions in a strategic, data-driven manner towards meeting the pressing mandates of both official external accountability as well as internal student-oriented school improvement.

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Chapter 7
Improving Content Area Reading Comprehension with 4–6th Grade Spanish ELLs Using Web-Based Structure Strategy Instruction

Kausalai (Kay) Wijekumar, Bonnie J.F. Meyer, and Puiwa Lei

Abstract Reading in the content areas of science, social studies, and current events is a difficult task that is even more elusive to Spanish-speaking English language learners. There is a huge increase in children transitioning from their L1 (e.g., Spanish) to L2 (e.g., English) in classrooms across the USA. These ELs face challenges due to a lack of fluency in decoding, vocabulary, and word, sentence, and discourse level complexities in English learning. Structure strategy instruction on the Web for English Language Learners (SWELL) is a web-based tutoring system that supports ELs in reading comprehension by teaching them about five text structures. In addition, SWELL provides two adaptations for ELs—Spanish Scaffolding (where students were presented materials in both Spanish and English) and English Hybrid (where students were given the option of seeking assistance in Spanish by hovering over words, clicking on sentences, or viewing a full page in Spanish). In this chapter, we report on the design and pilot studies conducted within five classrooms at grades 4, 5, and 6. Our results show improvements in reading comprehension measured by researcher designed measures.

Keywords Reading Comprehension • Spanish-speaking English language learners • Text Structure • Web-based intelligent tutoring systems

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1 Introduction

Reading in the content areas of science, social studies, and current events requires excellent decoding, vocabulary, oral language, and comprehension skills. Unfortunately most high-stakes assessments of reading comprehension show poor results for over 33 % of children in grades 4 and 8. The numbers are even worse for Spanish-speaking Latino children who are most at risk for school failure. In 2008, the US high school dropout rate for Latino adolescents was 22.5 % compared with all other subgroups combined (Fry & Gonzalez, 2008). English language learners are at particular high risk for poor educational outcomes due to a myriad of factors including poorer reading performance (Proctor, Carlo, August, & Snow, 2005). They are most likely to drop out of school and have a lower high school graduation rate than any other group. Spanish-speaking ELs also perform poorly on reading comprehension and mathematics standardized high-stakes assessments like the National Assessment of Educational Progress (2013).

Researchers have suggested that improving vocabulary skills and knowledge of comprehension strategies can improve reading comprehension outcomes for ELs (Baker & Dalton, 2011; Proctor, Dalton, & Grisham, 2007; Jimenez, 1997; Jimenez, Garcia, & Pearson, 1996; Proctor et al., 2005, 2011).

The SWELL project is an outgrowth of a successful web-based intelligent tutoring for the structure strategy (ITSS) project where we developed and tested the system to teach fourth through eighth grade children the structure strategy. The system showed statistically significant differences favoring the ITSS groups in large-scale randomized controlled trials in grades 4–8 (Wijekumar et al., 2014; Wijekumar & Meyer, 2012; Wijekumar, Meyer, & Lei, 2012, 2013). The goal of the SWELL project was to extend the ITSS system by presenting two specific adaptations for Spanish-speaking ELs—Spanish Scaffolding or English Hybrid.

We present our findings from the development and pilot studies here. Our findings support the growing research evidence base in support of the text structure strategy and web-based delivery of the instructional materials. Finally, this is the first development where the structure strategy has been used with Spanish-speaking ELs in grades 4, 5, and 6 and showed promise in improving reading comprehension.

2 SWELL and ITSS

SWELL has seven unique features noteworthy for all learners but very relevant to the EL learners who are the focus of this project. These design features are part of the existing ITSS and are also used within SWELL.

First, SWELL narrates (with a human voice) all procedural information and instructions to the learner. SWELL also has narrations for the text passages and feedback given to the learner (see Fig. 7.1).

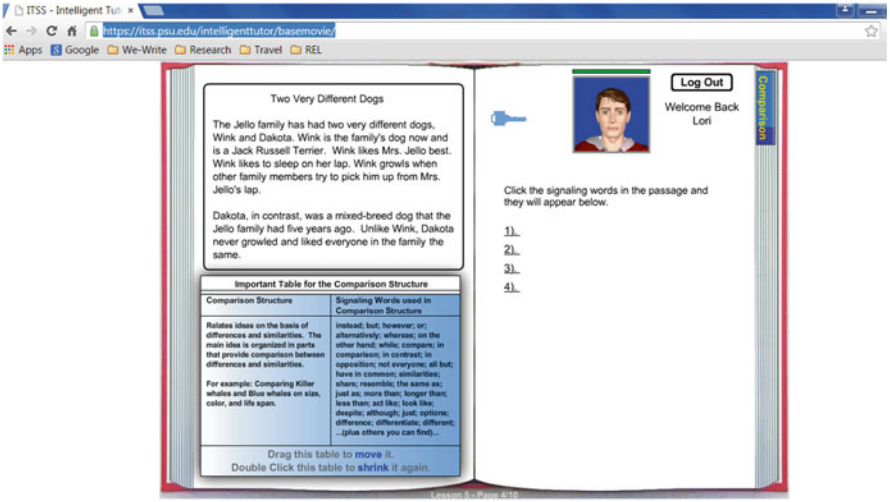

Fig. 7.1 The intelligent tutor narrates and provides instructions

Additionally, as the tutor (IT) reads a passage, the words blink on the screen allowing learners to follow the reading on the screen. This design mimics an adult reading to the child by pointing their finger on the words on the page as they read out aloud. This can assist EL learners who have difficulty processing the words. SWELL also has Spanish Language narrations for each procedure and passage. Animations are created to match the Spanish narrations. Lesson texts were carefully reviewed to meet the linguistic needs of ELs. Figure 7.2 presents a sample of the Spanish language adaptations for a passage comparing two different types of elephants.

Second, the SWELL system progressively gives more detailed hints to the learner depending on how many tries they have completed for the practice assignment. For example, if the student is on their third try and they have not mastered the concept, IT presents a pop-up window on the screen with very detailed helpful hints and reads the hints to the learner. The number of tries for each lesson and question vary from two to eight. This is designed to reduce any gaming related to tries. For example, when students realize that the system will give them more help after the second try, they tend to wait for the second try to get the correct answer. By varying the number of tries for each question, students cannot rely on a pattern to game the system.

Third, SWELL shows children how to use the structure strategy to read and comprehend texts in academic domains such as science, social studies, and current events. For example, in the first and second lesson students read a comparison text passage—differences between favorite Presidents—Lincoln and Washington. In the third lesson they read a science text comparing African and Asian Elephants. In the fourth lesson

Fig. 7.2 Spanish language adaptation comparing two different elephants

they read a passage comparing Olympic athletes, Dara Torres, Michelle Kwan, and Mary Lou Retton. This approach shows learners how the same text structures are applicable to all expository texts. To support the linguistic needs of ELs SWELL previews each lesson with vocabulary instruction and paraphrases of complex sentences.

Fourth, SWELL shows children how real-life texts are organized to promote transfer to environments where explicit signaling may not be readily available. This approach is part of the scaffolding process that allows gradual fading of supports as the student moves through the lessons.

Fifth, SWELL has alternative approaches to presenting information to the learners. For example, in the comparison of Olympic athletes, students click on a matrix showing how each athlete is compared on the sport they played, the number of gold medals won, and the year of their first Olympic win. In some cases a hierarchical diagram is shown to the learner focusing their attention to the logical organization of the text.

Sixth, SWELL shows learners how to combine text structure. For example, after completing about ten lessons on the comparison text structure and another ten lessons on the problem/solution text structure, students are shown how they can combine comparison and problem/solution in one passage. Many real-life texts combine text structures and it is important that students learn how to read such texts for the structure strategy to be effective in improving their comprehension of academic texts.

Finally, SWELL allows the teacher to access all the students' responses at any time through a teacher viewing tool and provides biweekly reports to the teacher on student performance and gaming. The teacher can also modify the students' pathway through the lessons if they see that they are able to understand the content. For example, the teacher can take place the student in a more advanced lesson if they believe that the student has the background knowledge to understand the content.

2.1 SWELL Extension 1: Spanish Scaffolding for Each Lesson

Students are provided narrated (and on-screen text) procedural information about each lesson in Spanish. E.g., for the earlier example on finding signaling words, "Cuando yo leo el pasaje, busco las palabras de señalización. ¿Puedes ver la palabra de señalización, diferentes en el pasaje?" After these instructions, students will read the passage in Spanish (with IT narrating the text in Spanish). Then IT gives the students a preview of what is expected in the English Language version of the lessons. The student is finally placed in the English lesson to apply the skills they learned in their L1.

This adaptation is designed to take advantage of the Spanish literacy skills that students may have. It has been shown that L1 literacy skills transfer very well to L2 as noted by Cummins' dual language iceberg theory. It has also been shown that tapping into their L1 literacy can aid their understanding of L2—hence the Spanish version of the passage (Slavin & Cheung, 2008).

Two versions of the English language passage are available to the learners. The first form of the text is at grade level readability. The second is an easier version of the passage created using features identified by previous research studies (Abedi, 2006; Williams, et al., 2009). Students are initially placed into reading the easier versions of the English passage and gradually transitioned into the regular grade level lessons based on their scores in each lesson (e.g., if they are able to score 80 % or higher on main idea tasks, they may be transitioned into the grade level passage in the next lesson).

2.2 SWELL Extension 2: English Hybrid for Each Lesson

Each SWELL lesson has an English preview lesson for the EL learners. Examples of elements covered in this preview are vocabulary enhancements (activities designed to identify cognates, roots, affixes, and morphological relationships; using words in context, and learning synonyms) and previewing sentences in easier versions. In these adaptations students can also click on specific words on the screen and hear the word meaning in English. Students may highlight a whole sentence and have IT give them an alternative simplified sentence to help them understand it. The vocabulary enhancements found to be effective in current research include those of August, Branum-Martin, Hagan, and Francis (2009), Beck, McKeown, and Kucan (2008), Dalton and Grisham (2011), Kamil and Hiebert (2005), and Proctor et al. (2011).

After completing these previews of the lesson, the student is allowed to complete the full lesson by clicking on signaling words, writing a main idea, and writing a full recall of the passage.

This adaptation is designed specifically for learners who do not have the Spanish literacy or oral language proficiency necessary to first practice in their L1. Instead we are trying to give them scaffolds to develop their English language vocabulary and background knowledge necessary to comprehend the grade level texts. Again, students initially read the easier version of the English passage prepared for the Spanish Scaffolding enhancement. As they gain confidence and their performance meets the thresholds set after the iterative studies, they are transitioned into grade level text passages.

3 Results from Pilot Studies

The research team has recently completed three series of quasi experimental research studies on the SWELL software with children in grades 4, 5, and 6. Our findings on a single subject design study showed children using the SWELL software made expected progress in the signaling word, text structure classification, main idea, and recall tasks. Usability tests showed that children using the English Hybrid version of SWELL were unable to navigate the system without explicit instructions in Spanish. Finally, the extended study with a matched control group showed that the SWELL classroom children outperformed the matched sample on signaling word and main idea tasks. The single subject design study is further described here.

In order to identify the necessary customizations for the many different profiles of ELs, we conducted a multiple-baseline single-case design Study 2 with School District B (Elementary—grades 4 &5 and Middle School—grade 6). In addition to the experimental data, we conducted a survey of the students about their opinion of SWELL.

The research questions were:

1. Does the Spanish Scaffolding Intervention improve performance on comparison measures (signaling word use and main idea quality)?
2. Does the English Extension Intervention improve performance on comparison measures (signaling word use and main idea quality)?

We followed the guidelines from the What Works Clearinghouse (Kratochwill et al., 2010) for designing and implementing a single-case study. We used a multiple baseline design using the staggered introduction of the independent variable (Spanish Scaffolding or English Extension) across different points in time. The study used the repeated and systematic measurement of the dependent variable (signaling word use and main idea quality) before, during, and after the active manipulation of the intervention (Spanish Scaffolding, Delayed Spanish Scaffolding, English Extension, and Delayed English Extension). The measurements at baseline and repeated at the completion of each intervention phase used three equivalent forms (Kratochwill et al., 2010).

The unit of analysis was the individual student. The school district provided the research team with measures of student's English reading comprehension proficiency and teacher ratings of the students' comprehension proficiency. In this study 61 students in grades 4, 5, and 6 were stratified on grade level and the assessment-based comprehension level and randomly assigned to one of four research conditions:

1. Spanish Scaffolding Regular start (SR)
2. Delayed start Spanish Scaffolding (SD)
3. English Extension Regular start (ER)
4. Delayed start English Extension (ED)

The following patterns were used in the design (L1S = Lesson 1 in Spanish; L1H = Lesson 1 Hybrid; P1 and P2 are pre- and posttest delivered on paper; C1 = first of computer presented repeated measures with equivalent comparison texts)

SR (Spanish Regular)

P1,C1,C2,C3, **L1S,L2S,L3S**, C4,C5,C6, **L3aS,L4S,L4aS**, C7,C8,C9, **L4.5S**, ……… C10,C11,C12, **P2**

SDelayed

P1, C1,C2,C3, ……… C4,C5,C6**, L1S,L2S,L3S**, C7,C8,C9, **L3aS, L4S,L4aS**, C10,C11,C12,**P2**

ER (English Hybrid Regular)

P1,C1,C2,C3, **L1H,L2H,L3H**, C4,C5,C6, **L3aH,L4H,L4aH**,C7,C8,C9, **L4.5H**, ……… C10,C11,C12,**P2**

EDelayed

P1,C1,C2,C3, ……… C4,C5,C6**, L1H,L2H,L3H**, C7,C8,C9, **L3aH, L4H, L4aH**, C10,C11,C12, **P2**

Participants within each research condition used the same lesson topics and practice tasks with different adaptations. The dependent variables (signaling word use and main idea quality) were measured using two paper and pencil tests (P1 & P2) that were used in previous studies and 12 equivalent forms (C1 to C12) developed by author and administered on the computer. The forms contained comparison passages each with 128 words and 96 idea units. Signaling word scores were based on students filling in four blanks to test understanding of signaling words for the comparison text structure (a signaling cloze task). The main idea quality was based on students writing a main idea for the passage (with the passage in view). These forms were modeled after the paper measures used in previous studies (Wijekumar et al., 2012, 2013, 2014; Wijekumar & Meyer, 2012).

Data points graphed below (see Figs. 7.3, 7.4, 7.5, 7.6, 7.7, and 7.8) comparing the regular and delayed conditions show that some causal conclusions may be drawn from the results. We present samples from Grade 4 in the Spanish and Delayed Spanish conditions below. The graphs are grouped based on similar teacher ratings and ACCESS scores showcasing the differences between the Spanish and Delayed Spanish participant performance. We begin with students with low ratings followed by medium and then high ratings.

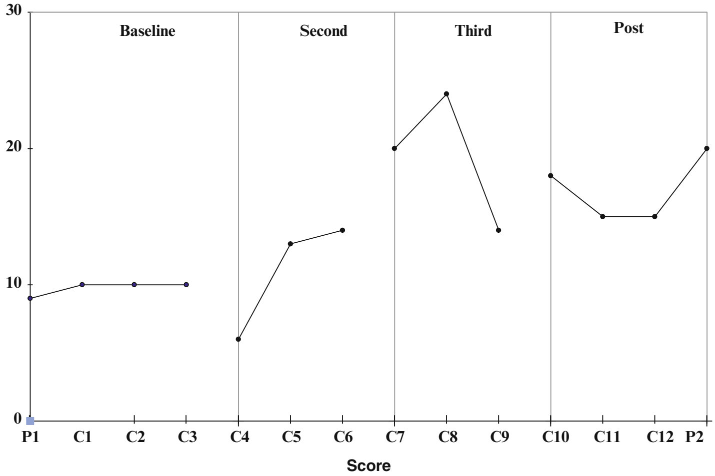

Fig. 7.3 Student: EL, Grade 4, Spanish Scaffolding, Eng level 2 Low

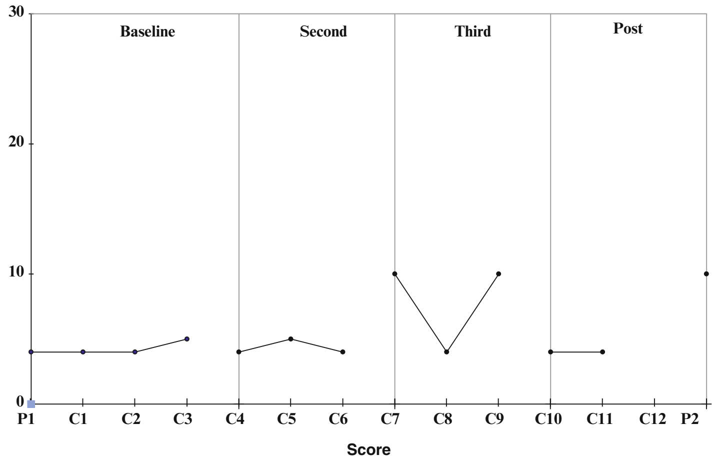

Fig. 7.4 Student: TA, Grade 4, Delayed Spanish Scaffolding, Eng level

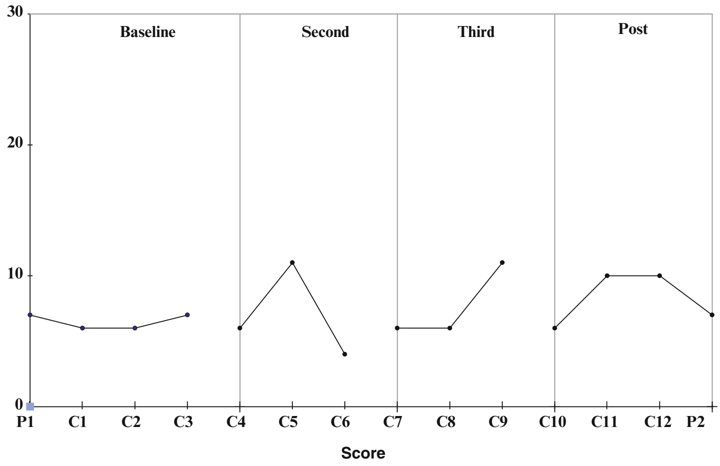

Fig. 7.5 Student: SU, Grade 4, Delayed Spanish Scaffolding, Eng level

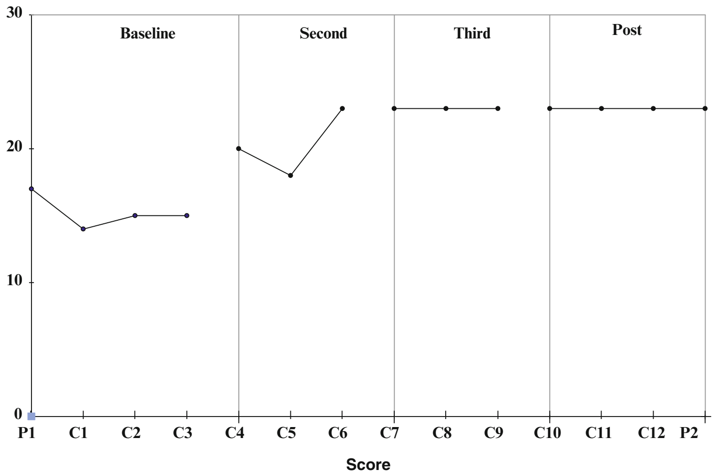

Fig. 7.6 Student: PE, Grade 4, English Hybrid, Eng level 1 Low

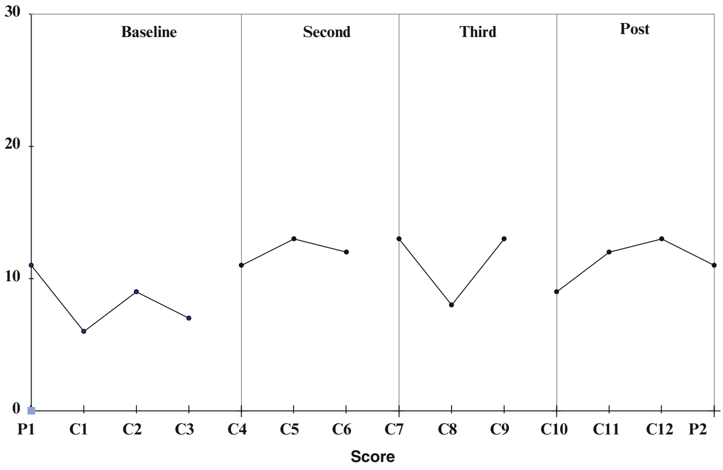

Fig. 7.7 Student: SA, Grade 4, Delayed English Hybrid, Eng level 2 Low

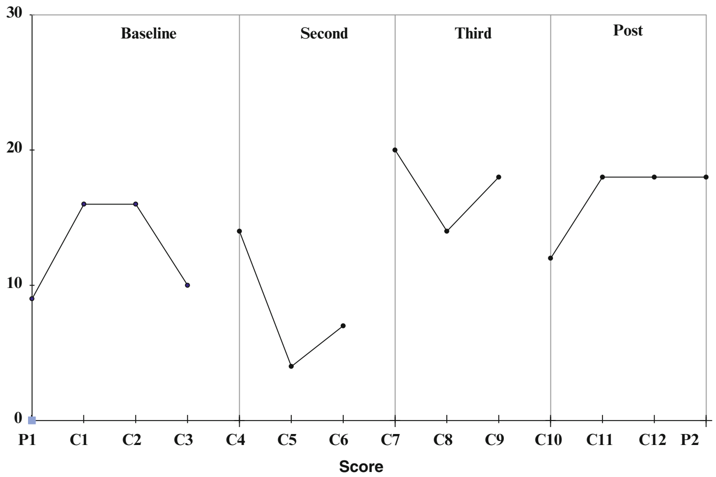

Fig. 7.8 Student PA, Grade 4, English Hybrid, Eng level 3

4 Conclusions

In this study, we extended the English version of the web-based ITSS to support and scaffold Spanish-speaking English language learners and gathered evidence on how children with low English reading comprehension skills performed when interacting with two SWELL adaptations. By using the single subject design were are able to explore the impact of the intervention components. The theoretical justification for the structure strategy instruction was confirmed with the study showing all the children using the software improved in their main idea and text structure classification tasks. Children using both SWELL adaptations (English Hybrid vs. Spanish Scaffolding) showed similar gains. It was observed and also confirmed with the teachers that most of children were not fluent in academic Spanish and therefore were unable to take advantage of the Spanish texts and supports in the Spanish Scaffolding version of the software. All the children were able to understand the instructions and interact with both versions of the software to show improvements. Finally, the textbook used in the participating schools recommended that children use the first and last sentence of the passage to write a main idea. This conflicted with the SWELL instructions and many children chose to follow the textbook instruction. For example, one child wrote "I found it in the first sentence" on the main idea question on the posttest.

The findings from this study show that SWELL adaptations can be useful to Spanish-speaking English language learners and teaching the text structure strategy can improve reading comprehension. It is also important to note that children need consistent and high quality instruction and practice for reading comprehension and changing practice within the classrooms is an important challenge for researchers and developers of curricula.

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Chapter 8
Teachers' Readiness, Understanding, and Workload in Implementing School Based Assessment

Norsamsinar Samsudin, Premila Rengasamy, Jessnor Elmy Mat Jizat, Norasibah Abdul Jalil, and Hariyaty Ab Wahid

Abstract Education is a major catalyst in the development of the country. School Based Assessment (SBA) is a new transformation in Malaysian education that required subject teachers to conduct formative assessment during teaching and learning process according to the procedures by Malaysian Examination Syndicate (MES). Thus, teachers play an important role in the implementation of the national education policy in order to develop students' potential and achievement in physical, emotional, spiritual, and intellectual. This requires teachers' contributions of effort, involvement, and overall professionalization. This study aims to investigate teachers' readiness, understanding, and workload in implementing SBA. Further, this study also seeks to determine the relationship between teachers' understanding and workload, as well as between teachers' readiness and workload. Participants comprised 260 teachers from primary schools in the district of Kerian. The results showed that the level of teachers' understanding and readiness towards implementing SBA is high. However, the workload level among teachers was also high. Correlation analysis indicated that there is a significant negative relationship between teachers' understanding and readiness with the level of workload.

Keywords • Readiness • School Based Assessment (SBA) • Understanding • Workload

1 Introduction

The success of an education system is determined by students' learning and performance. Ministry of Education (MOE) in Malaysia realized that the education system needs to go through a comprehensive and systematic transformation if

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Malaysia aspires to produce quality individuals who can compete in a global market (Preliminary Report of Malaysian Education Development Plan 2013–2025, September 2013). In line with the National Education Philosophy, MOE focuses on the holistic development of students that emphasizes the development of intellectual, spiritual, emotional, and physical.

Malaysia has undergone few educational policies to improve students' development and performance. The country implemented New Primary School Curriculum in 1983. However, the policy name has changed to Primary School Integrated Curriculum (KBSR) in 1993 (KPM, 2014). The assessment in KBSR was more on examination oriented instead of holistic education (Lembaga Peperiksaan Malaysia, 2012). Therefore, the policy has been reviewed, and new educational policy, National Education Philosophy and Curriculum Standard for Primary Schools (KSSR), was introduced in 2012. KSSR emphasized in holistic education, including reading, writing, counting, reasoning, ICT, development of social-emotional, spiritual, physical, cognitive, behavior, and value (KPM, 2014). In line with KSSR, the government announced National Education Assessment System (SPPK) and under this system, School Based Assessment (SBA) was introduced (JPN Perak, 2013). The main objectives of SPPK are to reduce the focus on examination, strengthen SBA, improve students' learning, continuous holistic assessment, and develop better human capital (Lembaga Peperiksaan Malaysia KPM, 2012).

There are five components of SPPK including the assessment of physical activities (sports and co-curriculum activities), psychometric assessment, school assessment, center assessment, and center examination. School assessment is divided into two parts: formative and summative (Lembaga Peperiksaan Malaysia KPM, 2012). For school assessment, each school is responsible for implementing their own assessment, which requires teachers to design, construct items and instruments, manage, mark the scores, record and report the assessment for every subject they teach. The aims of school assessment are to enhance students' learning and improve teaching effectiveness (Lembaga Peperiksaan Malaysia KPM, 2012). Furthermore, a few characteristics of the SBA includes: (a) able to provide a holistic overview of the knowledge and skills attained by students, (b) continuous assessment of teaching and learning, (c) flexible assessment methods according to students' ability and readiness, and (d) view students' achievement based on performance standards. The performance standard is a set of statements describing the achievement and mastery of an individual student within a certain discipline, in a specific period of study based on an identified benchmark. The performance standard will help inform teachers the most suitable way to assess individual student fairly in a focused manner based on the predetermined set of standards.

The evolution of national education system requires a paradigm shift among teachers. Drastic changes need to be made by the teachers to adopt the new education system. They must change the way they think and practice (Zaidatun & Lim, 2010). In every education plan, teachers play very important roles and they must fully understand the implementation of the new system (Nor Hasnida, Baharim, & Afian, 2012; Yusof & Ibrahim, 2012).

1.1 Problem Statement

The education sector in Malaysia demands high commitment among teachers to plan lessons, teach in the classroom, prepare students' report card, conduct co-curriculum activities, attending professional development courses, and collaborate with parents and the community. This is supported by Lemaire (2009) who found that teachers are burdened with tasks that unrelated to teaching and learning, extra-curricular activities, attending meetings, conducting student programs, and managerial duties. Furthermore, various reforms of education system contribute to teachers' stress as they are facing challenges and pressures to fulfill the requirements of the new system (Tajulashikin, Fazura, & Muhd Burhan, 2013).

In 2011, a survey by the MOE found that teachers work 40–80 h per week, with an average of 57 h (Preliminary Report of Malaysian Education Development Plan 2013–2025, September 2013). In addition, the National Union of the Teaching Profession (NUTP) has complained about teachers' workload to the Education Minister on 30 March 2010 (Khairul Azran, 2010). As SBA announced in 2012, teachers' workload increases as they have to conduct the assessment process from beginning. They have to key in the marks online in the School Based Assessment Management System (SPPBS). This means that teachers' understanding and commitment is crucial as they are empowered to assess their students (Mohd Noor & Sahip, 2010). Moreover, the large numbers of students in one class contribute to the difficulty in assessing every student (Harakah, 15 July 2013; Berita Harian, 15 Disember 2010).

According to Maizura (2010), readiness is an important aspect in determining the success and failure in implementing changes in the curriculum. For instance, the MOE had implemented PPSMI policy in 2003.

The policy required teachers to conduct Sciences and Mathematics in English language. This has raised objections from various parties. Finally, PPSMI policy was announced to be discontinued in 2012 and replaced by the policy of upholding the Malay language and strengthening the English language (MBMMBI). The implementation of PPSMI was considered unsuccessful because most of the teachers were not fully equipped with English language skills (Nor Safiza, 2011). Students also not ready to learn science and mathematics in English. Therefore, the purpose of this study is to investigate the level of teachers' understanding, readiness, and workload in implementing the SBA among primary school teachers in one district. The present study also seeks to determine the relationship between understanding, readiness, and workload.

2 School Based Assessment

The Malaysian education system has undergone various revolutions to ensure the development of intellectual and competencies of the society. Transformation in the Malaysian education system was seen as a catalyst in producing a competitive generation at a global level. National Education Assessment System (SPPK) is an assessment system that was introduced in the transformation of education. SPPK is the transformation of a system that focuses on achievement tests and exams (exam oriented) to a more holistic system. The aim is to provide a set of indicators to assess the potential of students and the willingness to learn. In addition, the new assessment intends to test students' mastery and achievement at school.

Assessment is an important component in education because it provides information about the progress of students to teachers, parents, and students themselves. The results of the assessment can help teachers evaluate teaching methods and activities in the process of teaching and learning in class. Previously, the Ministry of Education (MOE) is concerned about allegations that the current national education system is exam oriented based. Thus, in 2010 the MOE agreed that School Based Assessment (SBA) is implemented as part of the Education Transformation Program (KPM, 2014).

PBS is an effort to develop a holistic human capital through an emphasis on the mastery of knowledge, intellectual capital, acculturation progressive attitude, and practice of values, ethics, and high morals as recorded in the Education Development Master Plan (PIPP) and the National Integrity Plan (PIN) and as envisaged by the National Mission (KPM, 2014).

SBA is a holistic assessment that is able to assess the cognitive (intellectual), affective (emotional and spiritual) and psychomotor (physical) in accordance with the National Education Philosophy and Curriculum Standard for Primary Schools (KSSR). SBA is optimized for assessing academic and nonacademic of student achievement as it provides recognition and autonomy for teachers to implement formative assessment (assessment conducted during the learning process) and summative assessment (evaluation conducted at the end of a learning unit) in schools. The SBA component in the national assessment system includes School Assessment, Center Assessment, Assessment of Physical Activity, Sport and Co-Curricular, and Psychometric Assessment (KPM, 2014).

The School Assessment is designed, built, managed, checked, recorded, and reported by school teachers at the school. Sample assessment instruments that can be used are worksheets, observations, quizzes, checklists, report assignments, homework, and tests. Other than that, Center Assessment was administered, checked, recorded, and reported at the school level by teachers based on assignments and grading schemes issued by the Malaysian Examination Board within the period prescribed by the subjects. Meanwhile, Assessment of Physical Activity, Sport and Co-Curricular is implemented at the school level. It is administered, recorded, and reported through students' participation, involvement, and achievement in physical activity and health, sports and games, and other extracurricular activities. Above all, Psychometric Assessment is implemented at the school level to measure students' abilities (i.e., innate ability and acquired ability), thinking skills, problem-solving skills, interests, preferences, attitudes, and personality.

In order to ensure the effectiveness of the SBA implementation, teachers are required to comply the Standard Curriculum Document (SCD) and Performance Standard Document (PSD) (KPM, 2014). SCD contains topics that should be learned and delivered in the learning process while the PSD is the main reference for assessing and measuring students' mastery. Furthermore, School Based Assessment Management System (SPPBS) and Assessment of Physical Activity, Sport and Co-Curricular (JSK) were developed for recording, storing, and reporting student progress. Teachers are required to key in the students' data and the stored data can be printed as a report when required.

In conclusion, the implementation of the SBA can measure and describe the potential of individual students, monitor growth and help to increase their individual potential, and make meaningful reporting on individual learning. Therefore, SBA will ensure that students will achieve international standards in the field of knowledge, skills, and competencies through the education system.

3 Methodology

This study involved 260 teachers from 67 primary schools in Kerian district. A stratified sampling technique was used, where the researcher divided the schools into National Primary School (SK) and National-type School (Chinese and Tamil). Participants were randomly selected from each school. The instrument used in this study was adapted from previous research conducted by Kalawathi (2013), Nesan (2012), Fazura (2011) and NUTP Survey. The questionnaire is divided into three parts: demographic factors, teachers' understanding and readiness, and teachers' workload in implementing SBA. The questions are 5-point Likert scales ranging from disagree very much to agree very much. The reliability of the instrument has been verified by Cronbach's Alpha, in which alpha value of understanding is 0.893, readiness is 0.831, and workload is 0.792.

The data gathered from the participants were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics was used to discuss the participants' demographic information and participants' level of understanding, readiness, and workload. The differences between the participants' level of workload and gender and school category were analyzed using Independent-samples *t* test. One-way ANOVA was utilized to determine the differences between the participants' level of workload and school type. The relationship between participants' understanding and workload, as well as the relationship between participants' readiness and workload, was measured by correlation analysis.

4 Results

This section will discuss the demographic factors of the participants, the level of understanding, readiness, and workload in implementing SBA. The result of the differences between the level of workload and gender, school category and school type will be discussed too. Further, this section will reveal the findings on the relationship between the level of understanding and workload, and the relationship between the level of readiness and workload among teachers in implementing SBA at school.

As refer to Table 8.1, the majority of the participants are female (71.2 %). Male teachers are only 28.8 % of the total participants. According to school category, most of the participants are working at schools in the rural area (61.2 %). Those working in the urban area are only 38.8 %. There are 63.1 % of the participants working at SK, 21.5 % at SJKC, and 15.4 % at SJKT.

Table 8.2 describes the level of understanding, readiness, and workload in implementing SBA among primary school teachers. The majority of the participants have a high understanding about the SBA (70.8 %) and only 5.4 % of them have low understanding. For readiness aspect, most of the participants have a high level of readiness (71.2 %). However, 26.5 % of them have a moderate level of readiness. Most of the participants respond that they have a high level of workload (72.7 %). This is followed by 27.3 % of them that reported moderate levels of workload. However, none of the participants rated low level of workload.

Table 8.1 Demographic factors of the participants

Demographic factors of the participant	Frequency ($n=260$)	Percentage (%)
Gender		
Male	75	28.8
Female	185	71.2
School category		
Rural area	159	61.2
Urban area	101	38.8
School type		
National (SK)	164	63.1
National type-Chinese (SJKC)	40	21.5
National type-Tamil (SJKT)	56	15.4

Table 8.2 Level of understanding, readiness, and workload

Factors	Level	Mean	Frequency ($n=260$)	Percentage (%)
Understanding	Low	1.00–2.33	14	5.4
	Moderate	2.34–3.66	62	23.8
	High	3.67–5.00	184	70.8
Readiness	Low	1.00–2.33	6	2.3
	Moderate	2.34–3.66	69	26.5
	High	3.67–5.00	185	71.2
Workload	Low	1.00–2.33	0	0
	Moderate	2.34–3.66	71	27.3
	High	3.67–5.00	189	72.7

Table 8.3 Differences between participants' level of workload and gender and school category

	N	Mean	SD	t value	Df	p
Gender						
Male	75	3.68	.4703			
Female	185	3.92	.4344	−4.032	258	.000[a]
School category						
Rural area	159	3.90	.4479			
Urban area	101	3.77	.4640	−2.278	258	.024[a]

[a]Significant at 0.05

One-way ANOVA found that there is a significant difference between the level of workload and school type, F (2, $p=0.000$) = 40.260. The post hoc test indicated that significant differences exist between SJKC, SJKT, and SK. Participants at SJKC reported the highest level of workload ($M=4.3708$, SD = 0. 3954).

As displays in Table 8.3 above, there is a significant difference between the participants' level of workload and gender, t (258, $p=0.000$) = −4.032, $p<0.05$. Both male and female teachers reported a high level of workload. However, female teachers reported higher workload level ($M=3.92$, SD = .4344) than their male counterpart ($M=3.68$, SD = .4703). The result also shows that there is a significant difference between the participants' level of workload and school category, at (258, $p=0.024$) = −2.278, $p<0.05$. Although teachers in rural and urban area reported a high level of workload, teachers in the rural area rated higher level of workload ($M=3.90$, SD = .4479) than those in the urban area ($M=3.77$, SD = .4640).

Pearson correlation analysis revealed that there is a significant negative relationship between the participants' level of understanding about the SBA and their workload ($r=-.216$, $p<0.01$). The result also found that there is a significant negative relationship between the participants' level of readiness for implementing SBA and their workload ($r=.266$, $p<0.01$). These indicate that the higher the perceived level of participants' understanding and readiness about the SBA, the lower they would perceive of their workload.

5 Discussion

Overall results indicated that the majority of the teachers in the particular district understand about the implementation of the SBA. They were also ready in implementing the system. However, as the SBA is a new assessment system introduced by the Malaysian government, the majority of the teachers reported a high level of workload in implementing it. Teachers at SJKC perceived the highest level of workload as compared to teachers in other school types. In addition, teachers in the rural area experienced a higher level of workload than those in urban areas. This may due to the lack of the facilities and internet coverage in the rural area. In terms of gender, female teachers perceived a higher level of workload in implementing the SBA as compared to their male counterpart.

Findings showed that teachers in primary schools have a high level of understanding in implementing the SBA. Item analysis indicates that most teachers are benefiting from attending training sessions organized by MOE in which it managed to increase their understanding about SBA. In addition, support services and online mentoring by the Malaysian Examination Board is also helpful in improving their understanding about SBA. Besides, their readiness level is high in implementing SBA at school. Other research conducted by Ruhila (2012) and Ismadiah (2012) also found that the level of understanding is high among teachers in Johor. However, teachers' readiness in implementing SBA is only at a moderate level (Ismadiah, 2012; Nor Hasnida et al., 2012). Item analysis shows that teachers make a good preparation before teaching the KSSR subjects and always implement innovations in teaching and learning. However, teachers are not highly ready to try new strategies for implementing SBA. Furthermore, their level of readiness to go for more training about SBA was moderate.

This study found that the level of teachers' workload is high in implementing SBA. Factors that contribute to their high level of workload are: SPPBS is difficult to access, delay in databases due to poor internet coverage in rural schools, and they need to print a lot of instruments for evaluation purposes. In addition, the evaluation of ICT elements is difficult due to lack of computer facilities in schools. Furthermore, teachers face difficulties in evaluating weak students and those who always absent from school. These issues have been brought up by the National Union of the Teaching Profession (NUTP) complaining too many data to key in into the system for District Education Office (PPD) and MOE. They also complain that the SPPBS system always hangs and teachers have to reenter the data (The Star, 2013). Realizing the problems faced by the teachers, the government has taken continuous improvement to strengthen the implementation of the new system.

The results indicated that there is negative relationship between the levels of understanding and workload, and between the level of readiness and workload. Teachers who have low understanding and readiness about the SBA tend to have a higher level of workload. According to Mahamod, Yusoff, and Ibrahim (2009), teachers are the driving force and the main impetus to the process of teaching and learning in the classroom. Therefore, a teacher must be equipped with all related knowledge of the SBA. Implementation of formative assessment in the SBA requires serious changes among teachers. They need to change the perception of their role in improving student achievement and classroom practice (Hamzah & Sinnasamy, 2009; Nesan, 2012).

Evolution in the school assessment system in Malaysia requires a continuous process with several phases such as readiness, adoption, commitment, and institutionalization (Armenakis, Harris, & Feild, 1999; Lewin, 1951). SBA as a new national education policy requires the transformation of thinking and ways of working among teachers. The failure of the MOE in ensuring the readiness of teachers at the early stages of the change process will contribute to overall organizational failure in effectively managing change (Nor Azni, Fooi, Soaib, & Aminuddin, 2014). Willingness to change is described by the beliefs, attitudes, and intentions (Nor Azni et al., 2014). At this stage, organizational members should recognize the importance of change and switch their old practices to new ones. Failure to establish the readiness will affect a failure of change (Nor Azni et al., 2014). Therefore, school leaders are responsible for promoting teachers' readiness and commitment to change.

SBA as a new reform in the Malaysian education system requires educational leaders to take proper approaches to managing the changes. Kurt Lewin proposed that successful change should follow three steps: unfreezing the status quo, the movement to the desired end state, and refreezing the new change to make it permanent (Robbins & Judge, 2013). According to Osland, Kolb, Rubin, and Turner (2007), resistance to change is a natural reaction to change and part of the process of adaptation (p. 643). Hence, unfreezing the status quo refers to overcoming the pressures of both individual resistance and group conformity (Robbins & Judge, 2013, p. 619). This could make the transformation process from status quo to desired aims. The restraining forces that hinder movement from the existing equilibrium should be decreased. Management should focus on how to increase driving forces that direct behavior away from the status quo (Robbins & Judge, 2013). Thus, refreezing step stabilizes a change intervention by balancing driving and restraining forces (Robbins & Judge, 2013). In implementing the SBA in schools, the educational leaders should understand factors that affect teacher understanding, readiness, and workload. High understanding and readiness among teachers will decrease their perceive workload in implementing the new system.

6 Research Limitations

The study was conducted only in one district in Malaysia. Thus, the first limitation is the generalizability of the results. The findings of the study cannot be generalized to all teachers in the country. For the purpose of generalizing the results, more studies that involve larger samples are needed. Another limitation is related to the constructs that have been investigated. This current study investigated three constructs (i.e., teachers' readiness, understanding, and workload) in implementing the new school based assessment. However, there are several other factors that contribute to the effectiveness and efficiency of the new school based assessment implementation. For instance, the school leaders' support and leadership behavior, sufficient information and technology facilities, teachers' background, and teachers' experiences in their professionalism.

7 Conclusion

The SBA was introduced in 2011 to be implemented in all primary schools in Malaysia. Over the years, it is still early to evaluate the progress and success of the new system. The attitude of teachers who are not comfortable with the reform needs to be addressed. Exam-oriented emphasis needs to be changed to the assessment of individual student's skills and achievement. Implementation of formative assessment in SBA requires a serious shift in mind-set among teachers. Furthermore, teachers will be burdened and distressed in implementing the SBA if they do not understand about the system and if they are not ready to fulfill it. Teachers need to be more skilled in time management. Among the challenges in implementing the SBA is the use of online reporting system, management of document files, assessment of students who have different competencies in the classroom, teaching and learning strategies, and allocation of time for the implementation of activities in the classroom. Therefore, support from principals is crucial in implementing the SBA in schools. According to Muzammil and Kamariah (2011), good interaction between the school principals and teachers will contribute to the high level of job satisfaction and better performance among teachers. In addition, the management of the school should provide great assistance and adequate facilities for teachers in order to implement this new system.

As a conclusion, teachers in primary schools in the district of Kerian have a high level of understanding and readiness in fulfilling the SBA. However, they are burdened with high workload in implementing it. Since the significant negative relationship exists between level of understanding, readiness, and workload, possible way to reduce the workload is to ensure that teachers highly understand the requirements of the SBA and are always ready to implement it. Consequently, they will also change their perception to a more positive view of the SBA.

Findings from this study would be able to provide important information to MOE, schools, and teachers concerning the implementation of SBA in schools. Revealed aspects such as the level of teachers' understanding, readiness, workload, and the relationship between understanding and readiness to workload, provide better insights on how to effectively and efficiently implement this new assessment system. However, as the findings of this study cannot be generalized, more study is needed in order to contribute to the existing knowledge relating to SBA implementation in Malaysia. As the Malaysian government continuously makes an improvement of this new assessment, research on the level of parents' acceptance and the effectiveness of the system in students' performance should be conducted.

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Chapter 9
Digital Storytelling: Emotions in Higher Education

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Abstract In tandem with the deep structural changes that have taken place in society, education must also shift towards a teaching approach focused on learning and the overall development of the student. The integration of technology may be the drive to foster the needed changes. We draw on the literature of pertaining to the role of emotions and interpersonal relationships in the learning process, the technological evolution of storytelling towards Digital Storytelling and its connections to education. We argue Digital Storytelling is capable of challenging HE contexts, namely the emotional realm, where the private vs. public dichotomy is more prominent. Ultimately we propose Digital Storytelling as the aggregator capable of personalizing Higher Education while developing essential skills and competences.

Keywords Digital storytelling • Emotion • Higher education

1 Introduction

In the complex society we live in, with the unforeseen future demands and the need for competence development, it has become widely acknowledged that approaches to teaching and learning need to encourage greater student involvement anchored in constructivist perspectives. As Laurillard (1993), among others, has argued, higher levels of thinking and cognitive development occur in contexts that stimulate curiosity, problem-solving and reflective, critical thinking skills (see also the work of

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Schön, 1983 and others), where students are actively engaged in learning, in the construction of knowledge (see the work of Dewey, Freire, and Vygosky, for example). In the foreword of the book *Education for judgment: the artistry of discussion leadership*, Elmore (1991) states:

> The aim of teaching is not only to transmit information, but also to transform students from passive recipients of other people's knowledge into active constructors of their own and others' knowledge. The teacher cannot transform without the student's active participation, of course. Teaching is fundamentally about creating the pedagogical, social, and ethical conditions under which students agree to take charge of their own learning, individually and collectively. (p. xvi–xvii)

For many teachers in higher educational contexts, the challenge lies in attempting to understand the emerging educational context and the creation of learning environments that will make the development of higher-order cognitive abilities possible while encouraging teachers and students to thrive in what has been said to be the new technological paradigm: informationalism (Castells, 2000). The integration of technology in education has been acknowledged to enhance student engagement on all educational levels (Bates & Bates, 2005; Latchman, Salzmann, Gillet, & Bouzekri, 1999; Laurillard, 1993, 2013). As students become not only consumers but also active content creators, and literature demonstrates that technological integration in HE may constitute an interesting strategy to motivate student learning (see Bates & Poole, 2003; Daniel, 1998; Garrison & Kanuka, 2004; Laurillard, 1993; Rogers, 2000), it invites the question whether digital technology, particularly Digital Storytelling (DS) can possibly foster a more *personalized* Higher Education (HE). However, *getting personal* in HE, especially through *stories* seems to give raise to conflicting views. Based on the literature, we analyze and discuss emotion, interpersonal relationships, and storytelling in order to seek further understanding regarding the possible reasons for this contradiction and argue Digital Storytelling might be a feasible approach to reemerge the *emotional* and *personal* in HE.

2 Getting Personal in Higher Education

After thirty years of research, Pascarella and Terenzini (1991, 2005) concluded that "Modern colleges and especially universities seem far better structured to process large numbers of students efficiently than to maximize student learning" (p. 646), given that there are other essential dimensions beyond the cognitive skills and intellectual growth that HEIs that are still lacking. These include consideration of students' psychosocial changes, related to identity and self-concept; those related to others and the world; those related to values and attitudes; and those related to moral development. If HE is to be viewed as a facilitator for positive overall student development, all stakeholders involved need to rethink learning to include more than scientific knowledge.

Illeris (2003) conceptualized this interplay of multiple dimensions and processes into a model of learning. The author (2003, 2003, 2008) claims learning implies a series of processes that "lead to relatively lasting changes of capacity, whether they be of a motor, cognitive, psychodynamic (i.e., emotional, motivational or attitudinal) or social character, and which are not due to genetic-biological maturation" (2003, p. 397). This definition of learning demonstrates that it cannot be separated from personal development, socialization, and qualification. The author explains that learning implies the integration of two processes—an external interaction process between the learner and his or her social, cultural, or material environment, and an internal psychological process of acquisition and elaboration—and three dimensions—the content dimension, usually described as knowledge and skills, but also many other things such as opinions, insight, meaning, attitudes, values, ways of behavior, methods, strategies, and so on; the incentive dimension which comprises elements such as feelings, emotions, motivation, and volition and whose function is to secure the continuous mental balance of the student; and the interaction dimension, which serves the personal integration in communities and society and thereby also builds up the student's social dimension.

Illeris draws on the work developed by Vygotsky (1978) and Furth (1987), who acknowledged the connection cognition and the emotion. While cognition is connected to meaning making, the emotional content, Illeris defends, secures mental balance. The social dimension's main function is personal integration in communities and society. Other scholars who recognize this three-dimensional interplay in learning—meaning, personal (self and identity), and contextual interaction—are Lave and Wenger (1991) in what they describe as situated learning and Wenger (1998), on communities of practice, where learning is perceived as "a way of being in the social world, not a way of coming to know about it" (Hanks, 1991, p. 24).

While cognition is embraced and nurtured in HE, emotion and close interpersonal relationships are aspects that, despite the literature advocating their relevance, still tend to be disregarded in favor of more traditional approaches to teaching and learning, as these are considered private and beyond the scope of HE (see the work of Clark, 1983; Clegg & David, 2006; Clegg & Rowland, 2010; Leathwood & Hey, 2009; Morley, 2003). Thus, regardless of the current emphasis on student-centered learning approaches, considerable effort is made to maintain the firmly established boundaries and the distance deemed necessary.

2.1 Situating Emotion in Higher Education

Stones (1978) was amongst the first scholars to talk about the convergence of psychology and teaching, in what he termed as *psychopedagogy*, which means applying theoretical principles of psychology into teaching, in order to enhance teaching and its affective context, establishing a link between cognition and emotion. Although current literature often tends to associate psychopedagogy with learning problems, Saravali (2005), for example, recognizes the role of psychopedagogy in HE, where teachers are asked to facilitate meaningful learning at a time when students of all ages face personal development challenges, as we have seen. Saravali admits knowledge on student development and pedagogy is useful to help students, both socially and affectively. Emotions are essential for human survival and adaptation as they affect the way we see, interpret, interact, and react to the world that surrounds us (Horsdal, 2012). Boler (1999) admits emotions are underexplored in education. We concur with the author that it is not that pedagogy of emotions should prevail, and that teachers and students should disclose their innermost secrets and feelings to each other in the classroom. As teachers we do need to be aware of the intrinsic implicit and explicit relations in higher educational settings and consider the reasons why emotions have systematically been discouraged at this educational level.

Boler (1999) claims emotions are embodied and situated, in part sensational and physiological, consisting of actual feeling—increased heartbeat, adrenaline—as well as cognitive and conceptual, shaped by beliefs and perceptions. The author identifies three deeply embedded conceptions surrounding emotions, which may allow us to better grasp the reasons behind the apparent duel. Emotions have been conceived as private experiences people are taught not to express publicly; they are a natural phenomenon people must learn to control, and are an individual (intimate) experience. Finally, emotion has been excluded from the HE's pursuit of truth, reason, and knowledge. To address emotion is risky business, especially when, as the author argues, reason and truth prevail in HE. Emotions still tend to be associated with what the author describes as "'soft' scholarship, pollution of truth and bias" (Boler, 1999, p. 109), despite the proliferation of findings from the neurosciences advocating emotions as natural and universal and always involved in the learning process (see Scherer & Ekman, 2009, as well as Damasio, 1994, 2000, and Bartram, 2015 for example).

In his theory of consciousness, neurobiologist Damasio (2000) argues feelings and high-level cognition are intimately connected. The author claims a person's emotions can either inhibit or foment the brain's rational functioning. Additionally, consciousness of the world and of the self emerge in the same process. Damasio (2000) explains: "the presence of you is the feeling of what happens when your being is modified by the act of apprehending something" (p. 10). Thus, all that occurs to a person is emotionally laden. Damasio links not only cognition and emotion, but also the process of meaning making, or learning. Given the significance of this finding, the last 10 years has seen an increase in the literature on emotions in education. Schutz and Lanehart (2002) state "emotions are intimately involved in virtually every aspect of the teaching and learning process and, therefore, an understanding of the nature of emotions within the school context is essential" (p. 67). Immordino-Yang and Damasio (2007) emphasize the bound relationship between emotion, learning, and context in their recent article *We feel, therefore we learn*, where they discuss the relevance of emotions and social context on learning. The authors claim:

> Modern biology reveals humans to be fundamentally emotional and social creatures. And yet those of us in the field of education often fail to consider that the high level cognitive skills taught in schools, including reasoning, decision making and processes related to language, reading, and mathematics, do not function as rational, disembodied systems, somehow influenced but detached from emotion and the body. (p. 3)

These authors, among others, assert context enables social feedback, deploying emotions, which foster self-regulation, coping and an adequate response. Perry (2006) eloquently explains this process as such:

> Optimal learning depends on (…) a cycle of curiosity, exploration, discovery, practice, and mastery, which leads to pleasure, satisfaction, and the confidence to once again set out and explore. With each success comes more willingness to explore, discover, and learn. The more the learner experiences this cycle of discovery, the more he or she can create a lifelong excitement for, and love of, learning. (p. 26)

Zull (2002) claims it is hard to make meaning unless it engages students' emotions. They are inseparably linked to task motivation and persistence, and, therefore, to critical inquiry (Garrison, Anderson, & Archer, 1999). Caine and Caine (1991) argue teachers understanding of the human brain would allow them to take advantage of the natural processes so as to increase the students' meaning making capabilities. The authors claim the search for meaning is instinctive and occurs through patterning, a process where emotions are critical. The authors admit negative emotions, such as embarrassment, fear of others' reactions and threat, inhibit learning experiences (see also, for example, Ruthig et al., 2008), and affect memory (Kensinger & Corkin, 2003). Pekrun, Goetz, Titz, and Perry (2002) found that positive emotions such as enjoyment, hope, and pride were connected to deeper cognitive processing and critical thinking whereas negative emotions, such as boredom, were associated negatively with such cognitively demanding processing strategies. Dirkx (2001) and Clark and Dirkx (2008), for example, argue emotion and imagination are integral to the process of adult learning. Beard, Clegg, and Smith (2007) found that emotion is rarely acknowledged. However, they demontrate the importance of the affective, the bodily and sociality in relation to student engagement with learning in H. Shoffner (2009), when discussing preservice teachers, claims that reflection and the affective domain are closely entwined, positing that the personal plays an important, yet often overlooked, role in development.

As empirical studies proliferate and claim positive connections between emotion and learning in HE, some authors recommend a cautious approach and alert to the risks involved. Rai (2012) examined the significance of emotion in assessment through reflective or experiential writing in the context of professional practice-based learning. The author found that reflective writing raises important issues in relation to emotion for both students and teachers assessing their texts. While admitting the advantages of personal, emotionally laden reflective writing, Rai adverts to the full complexity of the impact of emotions. Tobin (2004) also explores some of the academic literature focusing on writing personal reflective accounts and contends that while teachers should encourage emotion in the classroom, there is a degree of risk. The author explains:

> By asking students to look beneath the surface of things, to explore entrenched opinions and values, to examine new perspectives, to write what they don't know about what they know, we are likely to make our teaching more exciting and more meaningful—for us and for them. We are also likely to make it more stressful and even a little dangerous. (p. 84–85)

For Tobin (2004) and Rai (2012) personal, reflective writing translates into a focus on emotions, in line with Schön's (1983) view of reflection as an emotional process. On this account, Brantmeier (2013) also claims learning that involves reflective critical-thinking activities allows students to be flexible and fluid, responsive to future yet unforeseen contextual needs. The author admits emotions invite vulnerability that, despite the risks discussed previously, is able to deepen learning.

Brantmeier argues the dialogic learning process should be based on the following premise: share, co-learn, and admit you do not know. Closer personal relations, whether between students or between students and teachers, step beyond the confines of what has traditionally been deemed as appropriate for HE. Personal or emotional aspects are met with mental barriers that pose difficulties to overcome but necessary to manage.

2.2 Interpersonal Relationships in Education

Emotions are not only deeply embedded in learning processes; they are part of the interpersonal dynamics, which comprise any learning context. Interpersonal relationships within educational contexts, whether they are teacher–student or student–student relationships, are complex and deeply rooted in social perceptions of teaching and learning.

Humans are social beings and therefore learning to be implies the development of interpersonal competencies. Within this scenario, emotions, interpersonal relationships, and learning cannot be disassociated, nor can we disregard any one of these aspects as they are intimately intertwined. Interpersonal relationships in education have, in truth, been the subject of numerous theoretical and empirical studies from multiple scientific perspectives over the last decades.

Given the social changes and the shift toward student-centered approaches in education, studies have emerged emphasizing the importance of interpersonal relationships and admitting the value of the teaching and learning process derives from the type and quality of the established relationships. For example, in his book *Learning to Teach in Higher Education*, Ramsden (2010) discusses the relevance of emotional aspects in interpersonal relationships, namely teacher–student relationships, while relegating teaching and learning approaches. The substantial amount of literature seems to confirm that positive teacher–student relationships have extensive effects on students.

A review of the literature establishes a connection between positive teacher–student relationships and greater student confidence, acceptance, happiness, and student commitment to learning (see for example, Abrantes, Seabra, & Lages, 2007; Cornelius-White, 2007). For Mendler (2001), a teacher–student relationship is based on a "personal connection" that ultimately seeks to develop student "academic and social competence" (p. 21). Pascarella and Terenzini's (1991, 2005) review on the effect of HE on students also provides incontestable evidence that interpersonal relationships are vital for student persistence and learning and suggest they are relevant for student overall success in HE. Similarly, Astin (1993) among others (see for example Pianta, Hamre, & Allen, 2012; Wubbels, den Brok, Van Tartwijk, & Levy, 2012; van Uden, Ritzen, & Pieters, 2014) established a direct correlation between student development and overall success and positive teacher–student relationships. While addressing student–student relationships, the author claimed: "The student's peer group is the single most potent source of influence on growth and development during the undergraduate years" (p. 398).

Kuh, Kinzie, Buckley, Bridges, and Hayek (2006) also draw on the work developed by Astin and report teacher–student interactions that extend beyond the classroom are positively correlated with personal growth in the areas of leadership, social activism, and intellectual self-esteem, and academic as well as social self-concept. The authors insist interpersonal relationships have a significant function in mediating student success in HE. Wentzel (1999), for example, discusses the connection between motivation and interpersonal relationships and the repercussions on student academic success. Spencer and Schmelkin (2002) studied students' perceptions on teaching and found that teachers' willingness to interact with them, to accommodate their special needs, to give feedback, perceive when they were having trouble, and know them by name affected students positively, as students associated teacher interaction with a positive teaching experience and with repercussions throughout their lives. Carson (1996) had also suggested that the impact of teacher–student relationships is long lasting. Student engagement increases and becomes meaningful when students perceive that teachers care about them and cater to their individuality (see also Fleming, 2003), without crossing the socially established boundaries.

Drawing on the field of neurosciences, Cozolino and Sprokay (2006) emphasize the need for a close link between learning and interpersonal relationships in educational settings, arguing that human brain needs social interaction to make meaning, to shape and reshape its connections, to adapt and readapt to an ever-changing world. The authors see the brain as a social organ, designed to learn through shared experiences.

Garrison et al. (1999) claim humor and self-disclosure are two examples of emotional expression that bring people together in a community, increasing trust, support, and the sense of belonging. In turn, the sense of belonging appears to have multiple and strong effects on emotion and cognition, as interpersonal attachments are considered essential for human motivation (Baumeister & Leary, 1995).

At a time when roles are shifting in HE, Schwartz (2011) adverts it is important to, as we have mentioned previously, be aware of the boundaries in these interpersonal relationships, that seem to be getting closer, especially between teachers and students. Schwartz contends that in order to void, what the author calls "the slippery slope" (p. 364), teachers distance themselves from their students, which may refrain the relationship from becoming rich, rewarding, and valuable, increasing the teachers' position of power and failing to foster greater student interpersonal competencies. Schwartz argues teachers need to find the balance to understand when and how the teacher needs to rim the boundaries to serve the student and the relationship. This study revealed that challenging the established boundaries enriches the mutual learning relationship and deepens the potential for the student development.

In HEIs where traditional teaching and learning approaches predominate, interpersonal relationships may be devalued. However, as we have been postulating, HE is about learning and student overall development is the work of HE. If science has proven and validated the connections, establishing the framework for teachers to work with, the option lies in their hands.

3 The Act of Telling Stories

The technological evolution has had a significant impact in educational practices all over the world. Yet, while pedagogical shifts seem slow to process, technological changes and implementations are fast-paced and widespread, perhaps suggesting that in the exponential economic and technological development we are witnessing, human development and other soft elements may have been overlooked.

Stories as a means of making sense of experience have proliferated across many different subject fields, among them, education. If we perceive the idea behind education as the re-contextualization of what has been learned in a continuous process of meaning making, i.e., to learn how to use the knowledge and skills in different contexts throughout life, we posit storytelling is, by far, the best tool humans possess. In this particular field McDrury and Alterio (2003) contend,

> Storytelling is uniquely a human experience that enables us to convey, through the language of words, aspects of ourselves and others, and the worlds, real or imagined, that we inhabit. Stories enable us to come to know these worlds and our place in them given that we are all, to some degree, constituted by stories: Stories about ourselves, our families, friends and colleagues, our communities, our cultures, our place in history. (p. 31)

Indeed the art of telling stories, whether orally or in the form of artwork, is one of the oldest methods of communicating ideas and learning (see for example, Bauman, 1986; Koki, 1998; Patterson, 1999). Storytelling persists as an unwavering tradition throughout the world and across different cultures, used to communicate and pass down information to younger generations, to encourage questions, stimulate discussions, and even to explain how one should live. Stories are a means to "socialization and enculturation" (Cruz & Snider, 2009, p. 380). Stories allow for the intersection of perspectives, which, in turn, will foment knowledge negotiation and construction. As Ricoeur states a narrative "construes significant wholes out of scattered events" (as cited by Walker, 1994, p. 296). Stories evoke in all engaging participants unexpected emotions, ideas and ultimately, unexpected selves, shifting perspectives on experience, constructing and deconstructing knowledge.

Traditional storytelling and educational technology can be said to have travelled divergent paths in education. While technology has seeped relentlessly into classrooms of all grade levels, storytelling seems to be imprisoned in lower grade levels (K-4), and the remaining grade levels continue to intently pursue Portuguese and Mathematics with a strict focus on standardized, national assessment. This system pervades HE. However, research has, time and again, demonstrated the connection between storytelling and higher-order thinking skills (Bruner, 1990, 2004; McAdams, 1993, 2001, 2008).

Stories are essential to human communication, learning, and thinking. Sarbin (1986) proposed the "narratory principle: that human beings think, perceive, imagine, and make moral choices according to narrative structures" (p. 8). This is corroborated by neuroscience and neuroimaging studies, which validate the claims that stories activate brain activity associated with cognitive processes (see for example, Fletcher et al., 1995; Gallagher et al., 2000; Mar, 2004). It is through stories that experiences gain meaning (Bruner, 1990; Polkinghorne, 1988) and, through reflection and interpretation, is then transformed into knowledge (Lave & Wenger, 1991; Schön, 1983). Stories enable the audience to learn by analogy, instead of direct experience (Jonassen & Hernandez-Serrano, 2002; Witherell & Noddings, 1991). Through storytelling, memory structures are construed (Schank, 1990, 1995) becoming easier to recall than scattered pieces of information.

Schank describes intelligence as the "telling of the right story at the right time in the right way" (1990, p. 241). Storytelling derives from the recollection and interpretation of an experience that has been significant; otherwise it is not remembered (Bruner, 1990; Schank, 1995; Thorndyke, 1977, 1990). It is this dialogic activity in storytelling process that enables learning and thus, human development. Learning occurs when reflection on experience is then transformed into a logical, meaningful story that is shared with others (Clark, 2010; Clark & Rossiter, 2008). This frames learning as a social, experiential, reflective process, integrating the cognitive, emotional, and social dimensions that Illeris (2003, 2008) identifies as essential to learning. From the author's perspective, stories, especially personal stories, motivate and engage the author in the act of creation. To create a coherent and effective story, the author must carefully reflect, select, prioritize, and organize what he/she wants to say and how this can be conveyed. As the story is told, the audience interprets, reflects, and connects to their own personal experience, construing new (mental) stories or reinterpreting older stories, in order to construe new ones. Furthermore, if interaction is possible between author and audience, or amongst the audience this (social) interaction fosters discussion and further reflection. The entire process is mediated by the intervenients' prior knowledge, their feelings in addition to the social and cultural context.

Despite the perceived value in storytelling, Cooney et al. (1998) have argued that once students reach functional literacy, story is cast aside, and regarded as an informal and recreational practice, not longer an essential skill for students. Pagnucci (2004) also posits while scholars promote the value of story writing, the academy often devalues narrative. This idea expressed by Bendt and Bowe (2000) summarizes what we believe is commonly accepted amongst educators, "Storytelling can ignite the imagination of *children*, giving them a taste for where books can take them. The excitement of storytelling can make reading and learning *fun* and can instill a sense of wonder about life and learning" (our emphasis, p. 1). The authors identify the advantages of storytelling, but associating it to a particular timeframe, when entertainment in education is socially acceptable. This has repercussions on higher levels of education.

Stories, especially personal stories, tend to be subjective and emotional. In fact, what is most significant in storytelling is the premise that most significant learning takes place during or after powerful emotional events (Witherell & Noddings, 1991). Whereas some regard the emotion in storytelling as powerful, others deem emotion as a weakness. Crafting a personal story is a highly complex and engaging activity for meaning making that couples cognition and affection, and links the self to others. Stories are used to create consistency, clarification, and coherence of the self, through subjective interpretation. Some criticize emotional and personal content in HE. However, research has repeatedly demonstrated the emotional content at the core of personal storytelling is connected to intelligence and higher cognition. It is a highly reflexive and recursive process which incorporates the essence of human development, identity, and education. By adding the digital to personal storytelling, we are able to incorporate the technical aspects, which drive the information society we live in.

3.1 The Digital Storytelling Process

Digital storytelling is an umbrella to refer to any type of media that assists in the act of telling stories. Authors use ICT tools, which enable the manipulation of digital content—audio, text, or images—to tell stories. Digital stories are the result of this process. Digital storytelling is rapidly proliferating throughout the world perhaps due to its unique characteristics. Digital stories thrive through the Internet, whether in personal webpages and blogs, social networks (such as Facebook), or even specific digital story sites (such as Storify,[1] StoryBook,[2] Cowbird,[3] Animoto,[4] ComicMaster,[5] Picture Book Maker,[6] among others). Thus, there are a wide variety of digital storytelling forms that range from the personal to educational, professional, and interactive entertainment. While some digital stories are video based, others are based on photos and others still on animations. Some are longer, other are shorter. Some are written; others are spoken, while some incorporate multiple media formats. The emergence of new digital technologies has given rise to what Couldry (2008) defined as a transition from mass media toward a more "personal media" (p. 32).

Notwithstanding the widespread use of the concept, not all digital storytelling tells stories based on workshop-format created by the Center for Digital storytelling (CDS). This Californian model (CDS model) best fits our approach and intentions as its emphasis is on *personal voice*, although we recognize it is not the preference in the field of education. Many of the studies in the field of digital storytelling refer to its origins and founders (CDS and Joe Lambert and Dana Atchley and Nina Mullen) but in practice the more personal elements are, very often, overlooked. The CDS model implies a *process* that has a set of recommended elements that are considered essential.

The typical 3-day CDS workshop begins with an introduction to the process, an overview of DS, a script review and development. The main purpose of the first

[1] Available at: http://storify.com/

[2] Available at: http://www.kerpoof.com/#/activity/storybook

[3] Available at: http://cowbird.com/

[4] Available at: http://animoto.com/

[5] Available at: http://www.comicmaster.org.uk/

[6] Available at: http://www.artisancam.org.uk/flashapps/picturebookmaker/picturebookmaker.php?PHPSESSID=9225166a1ad1eced34b763379f64cdc9

encounter, which we identify as the Story Circle, is to ***listen*** deeply to what each individual is ***saying*** and encourage others to listen. Lambert (2002) acknowledges the highly emotional and spiritual consequences of this first interaction. When there is trust, students will take risks and put themselves into the story in ways that are surprising and highly emotional. It is within this Story Circle that the story begins to take shape. Lambert claims, "one of the hardest, but most important thing to do, is getting started. Because many of the stories ask us to reveal things about ourselves that make us feel vulnerable, putting together a story can be a procrastinator's paradise" (2002, p. 31). While for some this first is an easy process, for others it proves to be a serious problem. Allocating the technological development of the story to last, DS captures "the human-to-human, face-to-face communication as the central means (p. 17)."

Each individual Digital Story is rooted in the Story Circle, which Lundby (2008), Thumin (2008), and Erstad and Wertsch (2008) claim to be a collaborative process embedded in specific social context, mediated by variety of unstated rules and social relations that bound the story chosen by the student.

After identifying the story, it is necessary to *write* a short, concise half-page tellable[7] script. For Lambert (2002), 200 words are enough to focus on the essence. The author welcomes metaphors, which translate into economy in terms of time and words. Each memory needs to be considered, planned, prioritized and then organized. The conversion into words becomes critical.

DS places the emphasis on the story although it is important that it is digital given the relevance of technology in today's society, on self-expression, self-representation, and communication (Lundby, 2008). A Digital Story implies a 2–3-min digital film consisting, in its simplest form, of a voice-over and self-sourced photographs, about a specific moment or event in the person's life (Lambert, 2002).

Lambert claims Digital Stories should include many, if not all, of the following seven elements: (1) Point (of View); (2) Dramatic Question; (3) Emotional Content; (4) Voice; (5) Soundtrack; (6) Economy; (7) Pacing. These are not meant to be strictly followed, but should be regarded as guides. Although the first three elements should be taken into account when writing the script, it is during production or the creation process that these elements are fine-tuned and linked to create the intended story.

Point of view means the point that is being made, what is being communicated, and the reason behind the story. Additionally, it could refer to the personal interpretation of what was chosen to disclose (directly, in the first person, or through a frame). The story should be tellable, interesting with a **dramatic question**, a plot and not a mere description.

The **personal** and **emotional** elements that derive from the very nature of DS are curiously the most criticized in the literature (Hartley & McWilliam, 2009) and, we

[7] Herman (2009) defines *tellability* as "that which makes an event or configuration of events (relevantly) reportable—that is, tellable or narratable—in a given communicative situation" (p.135). Herman notes that "a given narrative may be a rhetorically effective rendition of reportable events, or it may be only a teller's halting attempt to make sense of a situation with low tellability." (p. 34–35)

posit, the key that distinguishes this structured version of **D**igital **S**torytelling from the more generic digital storytelling. Lambert establishes an undeniable connection between DS and emotion. It is our belief that herein lays the crux of what could be the rehumanization of the world we live in.

For many, the realm of the digital is the most interesting part of the process. Story creators are encouraged to record a personal **voice-over**, given that the process itself establishes a connection between the storyteller and the story, allowing the memories of the event to surface as the story is uttered. Furthermore, voice cadence and style can be used as an additional mean-making element or simply to establish its rhythm (which Lambert refers to as **pacing**). This rhythm can also be conveyed through the **sound track**. Lambert (2002) states that the correct sound track is another mean-making element of the story. It is able to convey feelings, determine the mood of the story, and even change the way the visual components are perceived. It is another layer to the story capable of adding density and intensity and soaking it in emotion. Hull and Nelson (2005) for example comment that music is a pivotal means of expression and identification, especially for youth.

The final element **economy** seems to be the largest problem encountered. Lambert refers to economy, not only in terms of words, but also in the visual elements. The visual components of the story need to be thought out and organized in relation to and interwoven with the other elements and not as an illustration of the other modes of the story. Metaphors can also be applied to the visual layer of the story.

Technically, recoding the voice-over, the sound track and organizing the visual components of the story allow for more than the mere manipulation of audio, image, and video editing tools. With guidance, creators may develop essential media and ICT literacy skills, namely: how to analyze and create media for effective communication and understand the ethical/legal issues surrounding the access and use of Internet content.

The DS process comes to an end when the stories created are ***shown***, which we identify as Story Show. In Lambert's perspective, this is the most critical and successful part of the workshop. It is during the Story Show that recognition, learning, and emotional release merge as one. The viewers engage in a meaning-making process when they interpret the multiple layers of the stories. Lambert recognizes the dialogic nature of the stories and cites Birch, when she acknowledges:

> A key element of successful storytelling is dialogic. An audience at a storytelling event—as opposed to listening to a prepared speech or play—justly expect their presence to create a singular occasion. The story is not the same story it was when the storyteller practiced it before the concert began. A storyteller needs to acknowledge and adjust to, with some immediacy, the audience's responses, which provide a fresh and limitless source of energy, making each telling of a story a unique event. (as cited in Lambert, 2002, p. 87)

These perspectives corroborate our earlier discussion, contending the specific context and the each individual member of the audience construes the story uniquely based on their own individual tacit knowledge and past experiences. Thus, it is not so much about telling the story, but rather listening to a story at a particular moment, in a specific context, surrounded by a certain audience that impacts interpretation. "Digital Stories are simple but disciplined, like a sonnet or a haiku, and anyone can learn how to make them" (Hartley, 2008, p. 197), but more important that the actual digital story are the processual perspectives that, similar to a complex network of interwoven realities, are laden with advantages for education in general.

4 The Interconnected Threads of Digital Storytelling

We posit DS is the adhesive force capable of aggregating what research has identified as core. DS is capable of integrating different literacies and language skills, as it combines multimedia researching, production, and presentation skills with more traditional activities like writing and oral production skills. In practice, DS compels students to interpret, organize, prioritize, and make meaning of scattered events. Students are forced to reflect on their relationship with themselves and their relation to others. The preparation and creation phase requires students to search for and collect audio and visual materials, such as images, photos, and sound tracks, to support their story and then combine and organize them in such a way that allows them to create the effect they want. It obliges students to think critically about the meaning and effectiveness of multiple modes (elements) and their combination. This also confronts students with copyright issues on the Web. The narrative function allows students to tell a story with their own voice. Students need to reflect and decide on what to disclose. They are able to record and edit their stories as often as they want before finally presenting them to their teachers and colleagues, thus being able to improve their work until it is to their liking. DS is a personal self-representation, mediated by its limits. Length restrictions foster new ways of thinking, creativity, and imagination. DS is also user-generated media, placing the focus on the student instead of the teacher, giving students leeway to cater to their own individual interests and learning styles, toward a more personalized learning context. This however changes classroom dynamics and relationships, putting a spin in traditional lectured-based HE classrooms.

During the final viewing students may be confronted with positive or negative feedback to their final stories (as for example happens with movies uploaded onto YouTube). This fosters further reflection, interpretation, and meaning making in the author and the audience. The story circle and the story show are about listening, promoting community, trust and closer emotional ties between teacher and student and amongst the students. The content is personal and emotional, and thus empowering, motivating, and engaging. It seems that Digital Storytelling offers more than an opportunity to incorporate technology. As a process, Digital Storytelling demonstrates the capacity to aggregate the essence of HE: human (personal) development, social relational development, and technology.

DS is not just about creating digital stories; the foundations are embedded in story *telling*, in the act of sharing. DS in education can foster closer interpersonal connections based on trust, affection, and dialogue. The act of sharing begins in the Story Circle and continues through the Story Show. Significant cognitive development takes place in the interpersonal interactions prior to and after the act of creating the final story where self-reflection is the stepping-stone to dialogue, as advocated by the literature. This process fosters opportunities to connect and deepen relationships between students and teachers and amongst students. On the other hand, for students to talk about what is socially perceived as private is hard because they are afraid to be criticized. Students, like everybody else, worry about what impression they make on others and each element of the story is carefully selected and organized to disclose what they want. The DS process enables students to undergo a process of self-reflection on who they are and what they wanted to show, whether they then disclosed their thought or not.

Additionally, DS is emotional, sometimes upsetting because it focuses on issues presented from a personal perspective. Emotional and personal content is the precise focal point for criticism in DS, as society often cultivates the notion that the personal myth is too selfish, placing the self above society. McAdams (1993) argues, crafting personal stories is an "ongoing act of psychological and social responsibility" (p. 35) not selfishness. However, older people in particular have often been discouraged to talk openly about their personal lives, an idea that is still passed down to other generations. In today's society, emotional health cannot be viewed as secondary, but as essential to the twenty-first century student as the other persistently identified skills. While research on reflective teaching and emotional intelligence is abundant, the truth is that it remains a challenge to bring this practice into HE classroom.

The shift to personal perspective from which emotion stems is associated with higher-order cognition, positive student development and personalized, closer and less formal learning. Moreover and connected to emotion and self-disclosure, interpersonal relationships influence have significant impact not only at the personal level, but also on the academic and the professional realms as well. However, we would like to assert that while these three perspectives are intertwined and cannot be dissociated, our practical experience as teachers has demonstrated, the *personal* is still seen as unessential and even uncalled for in HE by teachers and students alike. Students are understandably reluctant to talk about themselves and what they perceive to be as private, too personal and emotionally laden content and not belonging to the field of academia. Teachers seem to have the same opinion, admitting that there is an invisible boundary that is not crossed unless students volunteer the more personal details. This raises the question of what is considered appropriate in HE, what is perceived as private, and what is considered public.

The largest obstacle in incorporating DS in HE seems to be getting teachers to recognize its value, to recognize that student reflection and expression of emotion enriches the learning process. Teachers need to acknowledge the alignment between DS and the intended learning outcomes in HE: DS encourages student inquiry, deeper analysis, critical thinking skills, visual literacy skills, visual and oral communication, teamwork, global and civic knowledge, as well as personal development—the rooted intentions of HE.

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Part III
Assessments and Analytics for Teachers and Decision Makers

Chapter 10
Addressing Standardized Testing Through a Novel Assessment Model

Martha H. Carey and Catherine C. Schifter

Abstract The No Child Left Behind legislation of 2001 spawned a plethora of standardized testing services for the high stakes testing required by the law. We argue that one-size-fits-all assessments disadvantage a wide range of students in the United States, including those who are English Language Learners, have limited economic resources, are designated as special needs, or are not reading on grade level. The SAVE Science project was developed to explore whether and how contextually driven assessments support these students in demonstrating their understanding of science content in grades 6–8. Preliminary findings from this 6-year study (not reported here) suggest that situating assessment in virtual environments may help students in answering content questions correctly and better understand their own science knowledge and learning process.

Keywords Critical theory • Standardized testing • Virtual environments

1 Introduction

The ubiquitous standardized tests developed by a small number of educational services companies and used in American schools contain questions culled from the cultural experiences of, and based on the language abilities of, the test content developers. All students are expected to be familiar with this content, but in truth it is often far removed from the diverse experiences and skills of actual students. And this expectation automatically disadvantages particular groups of students, particularly English Language Learners, students with limited economic resources (which can constrain exposure to varied cultural experiences) and students with special needs. Students taking such tests experience an existential dislocation:

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they must answer questions in a formal and rigid way, questions that may call for cultural acuity or information they may not have, written by unseen experts for whom this information is often intuitive. This can turn test taking into an Escher-like endless loop of apparent disconnectedness.

A Principal of a public elementary school in New York penned an editorial in the *New York Times* recently which touched on that disconnection, noting that English Language Arts standardized test content (developed by Pearson Publishing for the State of New York) presented students with questions that were confusing and inappropriate; there was a strong emphasis on questions addressing the structure rather than the meaning of texts and a lack of passages with an urban setting (Phillips, 2014). Her point is even more arresting when one considers the fact that, according to the 2010 census data, approximately 80 % of the population of the United States lives in an urbanized, non-rural area.

The standardized tests she describes carry high stakes for everyone involved, including students, schools, and teachers. And this pressure does not stop at the country's borders. The international PISA (Program for International Student Assessment) tests are administered in over 60 countries, and the test outcomes are often touted as key to global competitiveness (Lynch, 2015). For education policy makers, a poor showing reflects the fear that, as U.S. Secretary of Education said after release of the 2012 PISA scores that our students are basically losing ground, we are running in place as other high-performing countries start to lap us (U.S. Department of Education, 2013). Yet the PISA test questions on science knowledge (to cite just one example) have included decontextualized references to birthing calves, calf cloning, cattle breeders, and how a fly infestation on a farm impacted the health of a herd of cows (OECD, 2012).

The shift to high stakes testing is yet another national educational policy change in the United States that is an outcome of ongoing cultural and political conflicts at the macro level (Apple, 2007, p. 165). At the classroom level, in order to make these tests count, teachers must work within a new and seemingly permanent professional contradiction: they are trained to differentiate instruction to meet the needs of students where they are, but they then must standardize testing. This reflects a broader socio/political split between the idea of equality of opportunity, which has historically been a hallmark of American culture, and the idea of equality of condition. And teachers who embrace the notion that they can and should modify their practices, assessments, and content to better align with students' actual abilities and experiences are concerned with the latter—what Lynch and Baker (2005) have described as the equal enabling and empowerment of students.

Despite this, standardization has been embraced by school reformers and educational policy makers as a means of tracking the performance of and calculating the accountability of American schools. This leaves the ethical educator with few options. To counter the uniform application of these standards of knowledge to students who have varying skills, experiences, and language abilities, some refuse to give such tests, as a cluster of teachers in the city of Seattle, Washington did in 2013. Some have actively protested the test content and the standards aligned with them, most recently a group of teachers, parents, and administrators in

New York City. And the opt-out movement (where parents refuse, either formally or informally, to have their children take standardized tests) is growing, and in the state of Pennsylvania over the past two years, the percentage of student opt-outs on science, math, and English has spiked; New York state has experienced a similar jump (Harris, 2015; McCorry, 2015). But still others have worked *within* the standardization framework, to create test environments and test content that minimizes that endless loop.

Situated Assessments Using Virtual Environments (SAVE) Science was a collaborative research project between researchers at University of Maryland, College Park, Temple University, and Arizona State University focused on creating innovative models for assessment of learning in middle grades science. One aim of the SAVE Science project was to lessen the disconnect between test content and student experience through the creation of a new kind of assessment tool for middle school science students, where tests would be taken by navigating virtual game environments and students could use visual cues and inquiry skills to solve contextual problems. These assessments were proximal tests, directly linked to curricular concepts but delivered in a new context, and they also incorporated test content derived from distal measures—in this case, the statewide Pennsylvania System of School Assessment (PSSA) tests (Geier et al., 2008). This chapter presents a critical theory view of the importance of the SAVE Science project and what it brings to the dialogue around high stakes testing and differentiated instruction/learning.

2 Save Science

SAVE Science was funded by the National Science Foundation, and a goal of the project was to create, implement, and evaluate computer-based assessment modules for science content in grades 6–8. The modules were designed to enable students at varying skill levels and language abilities to perform a series of problem-solving tasks in virtual environments. Student activity in these virtual environments provided data to the researchers and to the participant teachers about how students applied content knowledge related to classroom curricula. Using a database of student interactions in a virtual environment, evolving patterns of scientific understanding among students were captured and analyzed. The alternative assessments developed through SAVE Science addressed several of the conditions needed for better science assessments, chief among them contextualization.

It has been shown that students have a difficult time applying their understandings of science content and their own experiences to the decontextualized questions found on multiple choice written tests, and the participant teachers in SAVE Science had found this as well with many of their own students. One very basic example of this (Fig. 10.1), taken from a recent PSSA test, was a question about fish and how they may adapt for weedy areas in freshwater lakes—a question that urban students may have to answer with *no* lived experience to draw from.

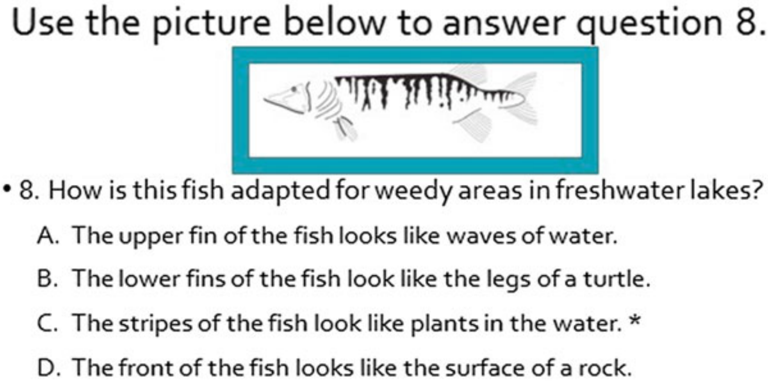

Fig. 10.1 Sample PSSA question (Adapted from the PSSA)

SAVE Science test modules provided students with contextualized questions by offering immersive virtual environments for students to explore. In one module, this same PSSA question was accompanied by an active rendering of that specific type of fish, swimming in its native habitat, so that students could observe the fish before answering the question. Another example: a SAVE Science module aligned with curricular content on measurements of pressure, temperature, and gas laws provided students with an virtual environment where basketballs were played with by various avatars at an indoor basketball gym and then were used on an outdoor basketball court in cold weather. Students had to determine why the basketballs bounced differently when inside or outside by gathering empirical data, analyzing that data, and reporting back their hypothesis and evidence to the appropriate avatar within the module. These activities were then followed by three standardized test items that correlated with the high stakes test questions related to this same content.

Evidence centered design principles, as outlined by Mislevy (2011), were used in the development of each of the SAVE Science modules. As the author noted, “the development of a valid simulation-[virtual-] based assessment requires the expertise from disparate domains come together to serve the assessment’s purpose (typically including subject matter knowledge, software design, psychometrics, assessment design, and pedagogical knowledge)” (Mislevy, p.2). In keeping with this perspective, the SAVE Science team comprised (1) an expert in science content, science teaching, and assessment design for science content; (2) an expert in designing virtual environments for assessment; and (3) a psychometrician. This team, along with 12 science teachers, four science education doctoral students, one science education postdoctoral fellow, and one qualitative research specialist, designed assessment modules for 7th and 8th grade content, plus two introductory modules. The two introductory modules were developed first: one familiarized students with the layouts and types of interactions they could have with avatars within the virtual worlds used in the modules, and the other familiarized students with the process of collecting data in order to answer the assessment questions in the modules. And all module content and assessment questions covered age-appropriate science knowledge, ranging from adaptation to gas laws to forces and vectors.

Working with two senior science teacher leaders from a large urban school district, the team identified specific areas of middle grade science curriculum determined to be difficult to assess through the high stakes objective assessments (i.e., urban students typically answered them incorrectly). Evidence centered design allowed the designers to create virtual contexts in which students could gather data on a problem presented as urgent, but within contexts that had been recently taught in the curriculum. The process of creating non-dislocating *visual* environments in which to convey this problem was, however, trial and error.

The first introductory module developed by the design team was created with a popular computer game in mind; it was set in the medieval era, on a sheep farm, and the primary avatar was a white farmer (see Fig. 10.2) who was concerned about his animals' grazing habits.

After collecting feedback from participant teachers and students about this introductory module, the next module developed was the basketball module mentioned previously. This module was not only set in contemporary times, but also located in a city, and the various avatars in that module were not only engaged in a familiar activity (see Fig. 10.3) but also visually represented the diversity of an actual urban population.

Using Vygotsky's (1978) zone of proximal development theory, the content in each assessment module was designed to be just beyond the capabilities of the students but close enough to not be too complex. The data gathered in each module included a movement trace of every non-player avatar students encountered (e.g., bumped into for information), an account of the data gathered by each student's use of the science tools built into each module, and a 3-dimensional time-stamped map

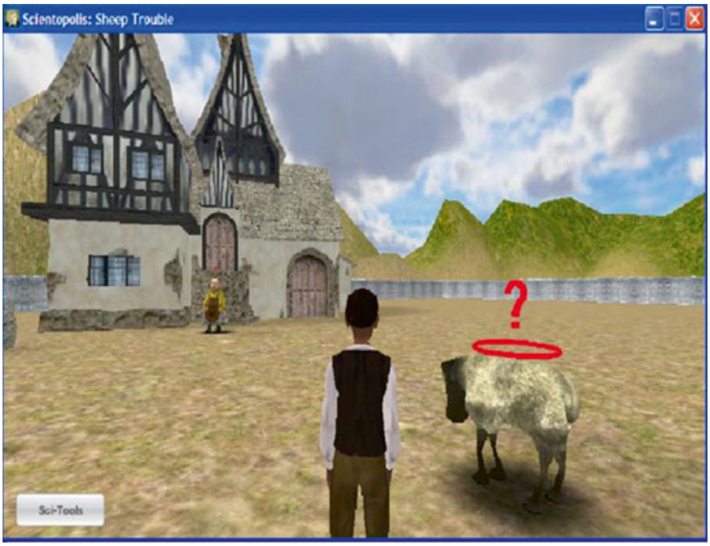

Fig. 10.2 Sheep farm (adapted from SAVE)

Fig. 10.3 Basketball court (Adapted from SAVE)

of each student's movements within the virtual environment. In the end, students answered both objective questions (based on original high stakes test items, but modified for the specific context of the module) and open-ended explanations of the data they had gathered. Students also had to rank the collected data in order of importance and give a solution to the original problem/question posed.

The results were a rich set of data that could be used to determine whether the student understood the question posed and collected data sufficiently to successfully respond to the assessment questions at the end of the modules (Schifter, Natarajan, Ketelhut, Carey, & Ryu, 2013 for additional detail). But analyzing these disparate data was complex, and the entire data analysis itself involved reflection on several levels. During one professional development session with SAVE Science teachers, for example, a review of the collected data led directly to questions about exactly how the researchers, and thus the teachers, should standardize and synthesize such data. One case discussed related to the Basketball module. The collected data showed that students who scored well on this module tended to follow a pattern of movement within the virtual spaces (from inside, to outside, back to inside) while students who did not score as well tended to move between these spaces more frequently.

What the researchers were looking for in the data analysis were correlations between random variables in data sets; regarding student performance with these modules, they were also looking for how patterns of interaction (collisions with others in the virtual world that led to questions and information exchanges) correlated with correct answers. In another module, the data showed that students who engaged in a specific set of collisions answered a summary question correctly. And similar correlations were shown between patterns of interaction and students answering specific questions incorrectly. From the perspective of the teachers, however, a review of the data and correlations still left much about these interactions and patterns of activity, and specifically what led to students' choices, unknown. The overall aim of the researchers was to develop usable, flexible automatic techniques specific to the module content that would allow teachers and researchers both to assess students' abilities to perform scientific inquiry based on freeform answer content as well as their behaviors within each virtual world. To that end, linear regression was used to analyze data. But student behaviors within the virtual worlds were often anything but linear, so this was an ongoing aspect of the data analysis discussions during the life of the project.

The data review by teachers also helped the researchers to hone in on questions that were "questionable" as well. In one introductory module, an answer offered for one question was that animals on the farm were "behaving in the way they do because they are evil." Several teachers noted that students would choose this answer simply because it is humorous even though they would know it was incorrect. As one teacher said, when they are in the middle of taking a test, it's hard for students to "pass up the silly" as a means of easing test stress—which raised the question of how this type of response plays into our understanding of assessment. Discussions such as these helped the researchers continually refine the variables in what Mislevy describes as the Conceptual Assessment Framework, the blueprint from which all SAVE Science modules were developed (Mislevy, 2011).

Most teachers are also not taught data-driven decision-making using multiple data points/sets, but typically use teacher-made tests or tests that are provided in a textbook. Mislevy's approach to evidence centered design suggests the more evidence the teacher has, the better for understanding student progress toward learning goals. To that end, the SAVE Science team developed a web-based dashboard which provided data to teachers on student interactions within the modules (movement/collision maps), as well as answer summaries. The dashboard provided teachers with a wealth of data, and that data provided the teachers with insights and information about the range and complexity of student inquiry behaviors.

As for the researchers, the data collected and analyzed from SAVE Science does initially suggest that it is possible to identify those students who clearly understand the science content in each module from those who clearly do not (Sil et al., 2012). By using cluster and textual analysis methods, we continue to refine the analysis toward a prediction model. Beyond the student data, the SAVE Science project results also add to the growing literature on the efficacy of computer-based assessments and provide a viable model for integrating assessment of content with scientific inquiry, and the contextualization of science knowledge, in virtual environments (Ketelhut et al., 2013).

3 Discussion

These efforts are one direct attempt to reduce the disconnection traditional standardized tests can cause among students, which is an issue that permeates education in the accountability era. Today approximately 21 % of the public school population in the USA is made up of English Language Learners (ELL) and only 3 % of these students reached proficiency or above on the 2009 National Assessment of Educational Progress (NAEP) reading assessment, as compared to 35 % of native English speaking students (Lara-Alecio et al., 2012). One component of ELL students' lack of proficiency on these tests is the "unnecessary linguistic complexity" of test items they encounter on such tests (Abedi & Gandara, 2006, p. 39). These students are directly disadvantaged by the test content they are required to master, test content developed by native English speaking test developers, presented out of context, and accompanied by minimal (if any) visual cues. Along those same lines, No Child Left Behind (NCLB) legislation ushered in an era of testing "focusing solely on student outcomes" as a means of improving schooling, but ELL students "disproportionately attend high-poverty schools with limited resources, and fewer schools offer bilingual education programs than did before the passage of NCLB" (Menken, 2010, p. 127).

Recent research has shown that American urban school districts overall are suffering the consequences of accountability systems based on test scores. It has been shown that "academically disadvantaged students in large cities are currently being left behind because the use of proficiency counts in NCLB does not provide strong incentives for schools to direct more attention to them" and that a school "that views AYP [the federally mandated Adequate Yearly Progress measure] as a binding constraint and also educates a significant number of students who have little hope of reaching proficiency faces strong incentive to shift attention away from their lowest-achieving students" (Neal & Schanzenbach, 2010, p. 280). Compounding this issue is the fact that the AYP measure is intended to reflect a rising minimum threshold for improvement, so that "schools that begin with low test scores, typically urban schools with a high percentage of children living in poverty in the USA, can have improving test score results, but because they do not rise above the minimum threshold, remain classified as failing…[and] because NCLB requires that by 2014 essentially all students need to pass every test, almost all the schools in the USA will be found to be failing" (Hursh, 2013, p. 577).

This conundrum reveals the limitations of, if not the fallacy of, an uncritical reliance on high stakes testing at the broadest levels. At the student level, research has shown that learning through a type of digital gaming similar to that developed by SAVE Science can be directly linked to learning outcomes, and that contextualized information in game environments allows us to "measure [students'] growth across time, and track different trajectories to mastery. It's an incredibly threatening moment for more traditional forms of assessment" (Herold, 2013, p. 577).

At the parent and teacher level, the movement to push back against overreliance on standardized testing continues to grow, particularly in urban areas. In Philadelphia for example, a *test-in* event was recently sponsored by the teacher's union. At the event, parents, teachers, students, and community members discussed the costs of testing, the impact on the Philadelphia school district of accountability policies that focus on testing, the impacts of standardized tests on various student populations, and how communities across the country have resisted high stakes testing. Similar events are being held in other states, as are student walkouts and test opt-outs (in Ohio and New Mexico)—and the school district chief of Chicago just publically explained that though she "personally and professionally believe[s] that to administer PARCC [the Common Core standardized tests] this year is absolutely not in the best interest of our students," she must go ahead with the testing or risk further funding cuts by the Illinois Board of Education (Strauss, 2015). And at the federal level, even though he is a proponent of Common Core standards, in early 2015 President Obama vetoed the initial No Child Left Behind 2015 reauthorization proposed by the U.S. Senate. He cited the overreliance on testing (as the arbiter of federal funding) as an undue constraint that prevents needed flexibility in educational planning at the state and local levels.

The SAVE Science project provided both critical positioning about such standardized tests, but more importantly, about differentiation. Teachers know that equitable teaching is about an alignment between content, instruction, and where students actually are. Good tests can achieve this as well. Yet all too often teacher-made tests tend to be about names, dates, and places and often don't provide opportunities for higher-order thinking. A key goal of contemporary education is for students to be able to take data from one place and apply this elsewhere, and projects like SAVE Science model assessments on the application of knowledge, not simply facts recitation. In that way, SAVE Science challenged the typical decontextualization of standardized tests, and provided teachers with an effective assessment tool and a range of student data, and students with opportunities to demonstrate their understanding of concepts and how those concepts connect to experience.

4 Conclusion

As noted above, teachers in the United States are inculcated with the concept of differentiating instruction based on student ability, including, but not limited to, English language proficiency, special needs, reading level, and prior learning. The age of accountability is symbolized by high stakes tests which include extensive reading passages to convey science content, which poses a conundrum for teachers. Do they follow ethical teaching and differentiate instruction, knowing that not all students will achieve the same level of proficiency or even basic knowledge, or do they teach to the test? SAVE Science was designed to challenge the notion of *what is a test* by providing students with contextualized questions so that they can demonstrate their understanding of content and scientific inquiry, and by involving teachers in ongoing discussion about assessment and decision-making based on a range of student data.

Two practical goals of the SAVE Science project were to develop new types of computer-based assessments that integrated and contextualized science content for students, and to enhance understanding of students' use of inquiry processes in science through the use of such alternative tests. A key motivating question for the Principal Investigators of the project was "Can we create something that's reliable and valid as an alternative to traditional testing?" And recent research supports the contention that assessments situated in virtual environments can also offer insights into student understanding not easily captured with other assessment methods and provides information about students' strategies in problem-solving (Ketelhut, 2007; Ketelhut et al., 2013).

The SAVE Science project explored how to improve students success in understanding and answering required test questions correctly. But a broader aim was about developing alternative forms of assessment which provide contextualized information for students and opportunities for them to demonstrate the ability to identify problems, collect data, and find solutions in a manner that does not alienate them or punish them for not intuiting knowledge that is not part of their lived experience. Preliminary findings from this 6-year study suggest that situating assessment in visual, virtual contexts does in fact help students to answer multiple choice questions correctly and also helps students better understand their own science knowledge and learning process.

These promising results provide initial evidence that situating assessments in immersive virtual environments and situating test questions in context can play a role in improving standardized high stakes tests, and also contribute to the ongoing conversation about what such tests measure, and how they are used. SAVE Science provided us with data about the use of virtual environment assessments with contextualized questions that may mitigate that endless loop of disconnection for students, enhance teachers' ability to both assess science inquiry skills and better utilize data for informed decision-making, and encourage test content developers to design assessments that do a better job of meeting students where they are.

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Chapter 11
An EVS Clicker-Based Assessment for Radical Transparency in Marking Criteria

Steve Bennett, Trevor Barker, and Mariana Lilley

Abstract Over four iterations of a large course (>180 students) in introductory e-media design in a first year computer science course, we have seen a year-on-year improvement. We believe this is done to the use of EVS clickers for feed-forward assessment: that is to say, a method of getting the whole class to evaluate previous cohorts' submissions in public and discussing them, bringing to light the various properties they possess and how this maps to the marking rubric. This is what we mean by *radical transparency*—making the criteria by which academic work is judged radically transparent. This impacts on the students practices as they attempt their assignment. Over time, the practice has become more refined, principally through a rewritten criteria sheet, better training samples, and finally the development of a hybrid in-class assessment: an assessment combining both formative and summative practices and relying on its visibly social nature for its transformative power. This involves (a) evaluating previous submissions (in a non-graded way)—allowing for the free exercise of subjective judgment not measured against any "authoritative" standard, but also (b) answering a set of objective questions about the work being assessed (what techniques were used to realize various effects). It ensures full cohort coverage together with engagement with the marking criteria.

Keywords Classroom response systems • Clickers • Feed-forward • Peer-assessment • Self-regulation • Exemplars

1 Introduction

In the preceding 4 academic years, on a first year introductory Computer Science B.Sc. module in multimedia development, the authors have used live feed-forward exercises using EVS clickers. By "feed-forward" we mean getting students to mark previous students work to better understand the assignment criteria. Usually, this is

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done in small groups with discussion. In our case, it has involved using a lecture theatre with around 200 students together. In it we use two projectors: one to display exemplars of previous students' work to be marked; another to display graphs and average values of scores input by students in the audience using EVS clickers as they mark according to the rubric. (An EVS clicker visually looks like a TV remote control, allowing the user to press on numerical or textual keys which is transmitted to a receiver connected to a lecture theatre computer capable of visualizing the aggregated choices made by the audience). For each previous assignment, students are led through the marking rubric and asked to mark the work as if they were the lecturer. Each dimension of the work being assessed has five attainment descriptors—students have to choose a number from one to five. Criterion by criterion, once everyone has voted, the average score is shown to the room as well as a histogram of numbers of students voting for each attainment level.

What they are evaluating is a Multimedia CV (resumé) assignment. This is a vehicle for students to be tested on their ability to design an interface and to be able to manipulate media to ensure the smallest possible file size. This tests the learning outcome of learning how computers digitize and store media and the various file size reduction techniques available. Students are asked to create five screens in their CV: a home page with an animation on it, and four other pages for work, hobbies, education and contact details. It is therefore a small assignment, but one which does require some planning, some sense of structure (particularly for the implementation of the audio player which needed to be independent of the other navigational actions of the user, i.e. moving between screens) a house style, and a very small file size. Finally, at the end of the course, in a one-hour session, all students are asked to remake their CV with new specifications of width and height—this is used in order to test students ability to use the tool (Adobe Flash), as well as to guard against cheating, as well as testing their use of efficient design practices to allow rapid subsequent redevelopment.

2 Theoretical Background

This technique (of getting students to mark previous exemplar work) has been done before, but not in live public sessions. Notable examples are O'Donovan, Price and Rust (2004), Hendry, Bromberger, and Armstrong (2011) and Wimshurst and Manning (2013). The theoretical basis for this kind of procedure comes most clearly from D Royce Sadler (1987) who beautifully expresses how just a few concrete instantiations of seeing the marking criteria used in practice can make marking criteria more comprehensible to students.

This area of research has much in common with the more researched area of student peer-assessment (see particularly the meta studies conducted by Falchikov and Goldfinch(2000), Topping (1998), Van Zundert, Sluijsmans and Van Merriënboer (2010)) and much of the claimed benefits are in common (particularly in the area of meta-cognition). However, peer evaluation studies have largely been paper based and asynchronous (feedback is collated and delivered subsequent to the peer-assessed event). Exceptions to this are Räihä, Ovaska and Ferro (2008) who used peer-assessment of student presentations in an HCI course. Peer scores were collected using clickers; however, results were not made immediately visible, and when they were, only to the presenting group (therefore, students did not see the scores of others). A much earlier example was cited by Banks (2003), recollecting the use of clickers for the peer-assessment of student presentations in a Data Communications Networks course (10 years earlier in 1995). On this occasion, students presented, and then after all had presented, the marks per student (on a 10 dimension marking rubric) were displayed to the whole class after 10 discussions ensued and students reflected on their presentations. The authors have themselves used live peer-assessment with clickers on a masters' course called Multimedia Specification Design and Production (Bennett and Barker (2012)).

However, feed-forward, because it does not impact on the actual grades of the student whose work is being assessed (because they assess the work of a previous cohort), may be more effective at improving meta-cognition in the student assessor.

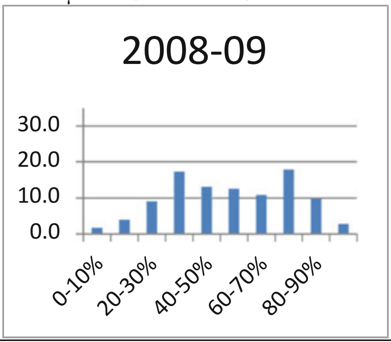
2.1 Live Feed-forward and Students' Reactions

In order to achieve the engagement of the entire cohort, each year we run this evaluation event twice: the first time formatively—looking at work done by previous cohorts, marking them and discussing the marking. The second time it is run summatively (credit bearing)—where (in the first three iterations of use with clickers) students received a mark according to the level of agreement between their grading and that of the tutors. However, this caused hostility in the first and third year it was used. Therefore, on the final occasion we created hybrid assessment type involving a formative part evaluating previous students' work (which was not graded) followed by a small 10 question test on some of the practical features and techniques used in those previous artifacts which could be marked on an objective basis. It is therefore both summative and formative; however, we argue that the power of this technique of live feed-forward occurs in the way it causes the student to actively participate in the activity of grading, and also, in the way it allows them to compare the grades they themselves have awarded with those awarded by the tutors and the rest of the class.

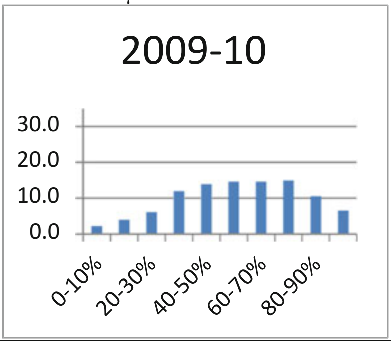
3 e-Media Design Course Historically

The six graphs below represent the banded scores for the CV assignment on the course. The x axis represents the final student percentage score in bands of 10 % (e.g. those who scored between 0 and 10, those who scored between 10 and 20). The y axis represents the percent of the cohort in each decile. In this list, only students scoring above zero have been included. Although the first intervention using live feed-forward occurs in 2010–2011, we have included the two previous years in order to demonstrate that the results obtained in 2009–2010 were not merely the result of the vastly larger cohort in that particular year.

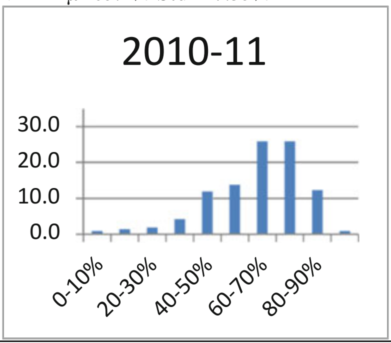
2008-9
N=173 μ=55.3% Std:22.12%



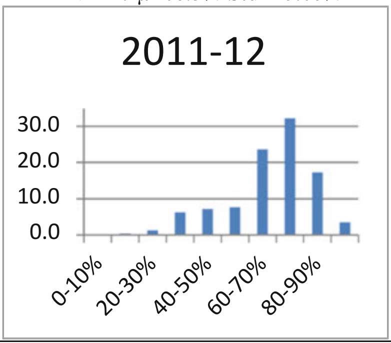
2009-10
N=273 μ=58.3% Std=22.726%



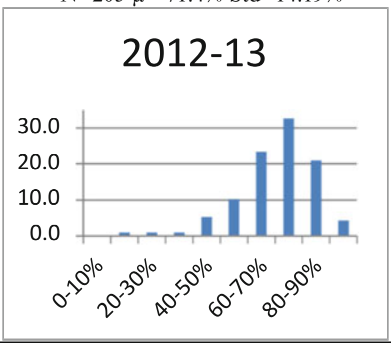
2010-11 *EVS feedforward assessment used*
N=214 μ=65.4% Std=17.35%



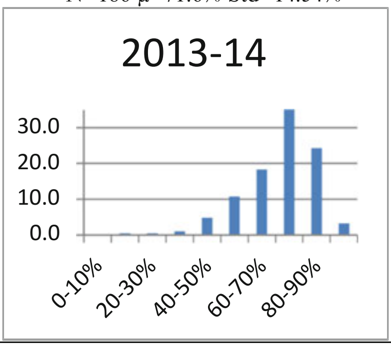
2011-12 *Rubric Rewritten*
N=220 μ=68.3% Std=15.68%



2012-13 *Teaching Materials changed*:
N=205 μ =71.4% Std=14.19%



2013-14 *Exemplars & event changed.*
N=186 μ=71.6% Std=14.54%



As can be seen, a significant improvement takes place not only in the indicators of average grade, but also in terms of the shape of the distribution. In 2009–2010, the distribution becomes more normal and shows a small overall improvement in average grade. 2010–2011 was the first time we used the feed-forward method and did so with the identical criteria used in the 2009–2010 assessment. This small improvement however came at the cost of some student negativity owing to the manner in which the feed-forward was conducted: namely, students were given marks by how near their marking pattern coincided with that of the tutor. Students complained of being asked to guess what we the tutors were thinking.

In 2011–2012, therefore we rewrote the criteria to remove the subjectivism from the more basic things being tested and used Likert scales for higher order criteria (appropriateness of design for instance). This generated less controversy and the greater clarity in the earlier criteria meant students could address the basics more easily, and the lowering of students getting 90 % or more arose probably from the fact that achieving all the higher order criteria became harder.

However, the opposition of students to being marked for their coincidence with the tutors' marking in the feed-forward events still continued to be expressed in 2012–2013. Also some dissatisfaction was expressed with regard to the exemplars: in order to anonymize the work of students on previous iterations of the course, we replaced pictures with cartoon images and changed personal details—which meant the exemplars lacked realism. This year also involved a big rewrite of the teaching materials when we moved to a set of e-books rather than the open education resource entitled "Introduction to Flash MX" which we had been using up to that point (see http://goo.gl/dm52ef).

In 2013–2014 with the rubric only marginally changed, we changed the modality of undertaking the feed-forward. Just as in previous cases, there would be a practice session and then there would be a marked second session—however, the marked second session involved both a formative assessment of the works being evaluated, as well as a small summative test on the objective properties of those works (for instance, what technique allowed a certain effect to appear). Additionally, in response to the criticism of the quality of the training set, we introduced a new much better training set—producing past CVs but anonymizing the students' personal details, (including putting stock pictures of another person of the same age, gender and ethnicity in their stead). This was meant to answer the concerns raised both about the training set and also about the method used for crediting participation in the feed-forward events.

3.1 Making Sense of the Data

At this point, it is worth introducing some caveats about the improvement in students' scores being seen. Any course over time, in so far as its teachers reflect and make changes based on feedback obtained from each running of the course, is likely to improve. Also, besides the introduction of live feed-forward marking, there were also effects caused by:

1. Different rubrics used
2. Different teaching materials used
3. Different numbers of students
4. Different feed-forward logistics and modality

However, given that the quality of the overall student work has increased over that time, we believe therefore that this feed-forward technique has had some clear positive influence. At this point, the question becomes: what is it that students are doing differently in their work subsequent to the EVS evaluation sessions?

The principal evidence we will look at will be from a focus group in the final iteration of the course. This was the iteration when the tutors believed we had the best running of the course, owing to:

1. A better training set (of six prior CVs)
2. Absence of technical issues
3. Uncoupling of student evaluation and tutor evaluation

Three students took part in this focus group. Their scores in the final artefact were

Score (%)	@ Percentile	Rank
83	77	43rd out of 186
80	71	55th out of 186
74	45	103rd out of 186

4 Major Themes

4.1 Self-Regulation

On the premise that students achieving higher grades are either doing more work or doing more efficient and goal focused work we sought to find out how students regulated their effort of the course of an assignment. This course takes place in the first semester of their university career when they are making the transition to university study. Therefore, we began by asking the students to state how they experienced that change:

One student said

> "It feels like in school it is more like you have a baby sitter but in university the lecturers are more guiding you but you don't have to take part"

Another said

> "There is a lot of self-progress, where you track yourself"

The question then becomes of how students track themselves. Or in other words, how do they know that what they are doing is right?

The students seemed to do self-evaluation on two levels: one was like a checklist, involving a simple comparison with the detailed criteria of the rubric, and effectively being ticked off as they were done. The other involved something less tangible, a feeling of dissatisfaction which students found difficult to put into words which required further work.

An example of the first type is in the following exchange from the focus group:

Student 1: The sheet that you get basically gave us a list and markings of what you guys expected so it kind of told us exactly what to do.

Tutor: If it told you exactly what to do, while you were writing out your CV you were kind of ticking bits off?

Student 1: Well what I did was I read through all of it, then did my CV, then read through it all again and checked everything and compared it with my CV and then changed things around it.

Tutor: That is really interesting. Did you two do the same?

Student 2: Yes, pretty much. I just followed the requirements sheet.

Tutor: And did you do it formally as in ticking things off or did you do it…

Student 2: I used the … and come back to them eventually but I tend to do the easiest bit or the bits that I am not struggling with.

Tutor: So you did the easiest bits and sort of ticked them off and then you come back to the harder bit later. What were the harder bits?

Student 2: The ones that involved more—making a background colour in grey is easy; it just involves doing something in stuff but making things move around or something that involves … so you would come back to that.

Examples of the second type come in the following statements:

I created an animation, but when I got into the class I looked at it again; I felt like it is not really finalized.

It didn't feel right to me; when I brought it to the class, I had to just quickly change it.

You kind of know when you have done something 100 %.

Well if you are not confident with something that you have done, then you know that you might get a mark that you might not like.

While the former type is more directly tied to the explicit criteria of the rubric, the second type (feelings of non-finalization, or "didn't feel right" or not "100 % done") also arises from a comparison with the standards that the rubrics, and, we believe, are internalized through the evaluation events.

4.2 Clarity of Criteria

How does that internalization take place? This focus group mentioned the evaluation session as being crucial to getting a sense of the level required. The primary benefit was the clarity of the criteria. But two factors seemed to be instrumental in achieving this effect. The first was the greater attention students showed arising from using the clickers in the evaluation sessions:

> the clickers forced you to listen because then if you don't listen then you miss the question and then you won't answer it so the clickers—whereas most people would fall asleep in that lecture or go on Facebook or whatever, when you have the clickers there everyone starts paying attention.

But the other was the commentary on the results given by the tutors in response to the student evaluations:

> I think we could have all just looked at the CVs and gone that is a good one, that is a bad one but when you guys went through it and explained why that is a good one and why that is a bad one and pointed out the bad things and the good things then everyone got a better idea of what you expected of us.

This backs up what Royce Sadler (1987) has said about the value of concretizing abstract attainment criteria in specific exemplars which embody them. But while his research has typically focused on the understanding of higher order criteria, the benefits also help with the satisfaction of the lower order criteria.

As well as being able to avoid simple errors—it also helped with impasse management. Having a clear sense of what they are trying to achieve, seemed to help students identify points at which they were unable to get to their goal. As quoted above:

> making things move around or something that involves a little more work into it so you would come back to that.

Students also sought the help of peers when attempting more difficult parts of the assignment.

4.3 Help Seeking

One student talked of an impromptu Facebook group that four students had set up. Asked what they talked about in that group. He said

> People were asking questions, they were asking more to do with animation and sound, less than the colours because they were pretty easy because you just get a palette and you just pick whichever one, its trial and error really, you don't like a colour or it doesn't match you just change it and that is pretty easy.

Another student described sampling music for the background audio.

Student: I think there was a Facebook group but I didn't use it. I had to ask a friend for help on one thing and my friend asked me on one thing too so I guess we just helped each other.

Tutor: So what were those things?

Student: My friend asked me if I could help her on the sound because they couldn't get the sound buttons to pick up the music and I had forgotten how to make music like package shorter.

The fact that students used Facebook rather than the University's own Virtual Learning Environment (*Studynet*) for help seeking is striking. One student said

> We had a couple of people on Facebook asking questions in a group chat so yes there were help but I think the fear of posting on studynet—its a bit dangerous—in a smaller group on facebook where everyone is your friend

> …So if you do it on studynet then everyone can see it and then people may laugh at you in a way.

4.4 Status of Rubric

While a detailed rubric has been a feature of the final assignment since the 2008–2009 iteration of the course, it has only been seriously attended to since the introduction of EVS clicker-based evaluation events. What seems to have happened is that the ritual of the collective marking activity seems to have enhanced the authority and tangibility of the rubric.

One student said:

> It is when you look up at the mark sheet and what you learn in the lectures they say the same thing so when you attend the lecture and you do that with the clickers then you know that immediately when you get to them sheets that that is one of the requirement that you should fill in.

Here, we clearly see the centrality of the rubric and the way it acquires extra authority through being enacted in public at the live evaluation sessions. All of this is similar to the participation-reification duality described in Wenger's Community of Practice (1999). The rubric represents a reification and codification of the practices necessary for a successful multimedia CV. The participation is the kind of work students do outside lectures and practices which make that successful multimedia CV—but also comprises the informal collaborations, help seeking and work planning which we have noticed above. Having learnt how to apply the rubric, by collectively marking 3–6 pieces of work together, the core centrality of the rubric becomes apparent to the students.

5 Achieving Full Cohort Coverage

5.1 Grading Students' Grading

A problem that has endured since first attempting this intervention is how to ensure full cohort participation in it. Were we to make participation in the evaluation sessions a purely voluntary experience the danger is that the benefits would only extend to the attendees. In fact, in the formative evaluation event 102 students attended, in the one with a summative quiz at the end, 181 students attended.

In the first three iterations, we ensured this by actually grading the students' evaluation of previous exemplars—that was done by measuring the difference between the scores the tutors awarded and the scores the students awarded. Because of students' resistance to this, we abandoned the practice in the final year—but we still needed to find a way of making participation mandatory.

5.2 Hybrid Assessment

In order to resolve this problem—requiring full-cohort participation but without grading according to marking coincidence—we designed a hybrid assessment. This required the students to attend a session—the first part of which would involve the evaluations of a previous cohort's artifacts which was not grade bearing. Then, there would be the second half that would involve answering 10 objective questions about those artifacts (e.g. which tool was used to achieve effect x) which would be grade bearing—this meant it required everyone to be present—but the grade bearing part was a truly objective test, rather than one based on coincidence of subjective judgment.

This therefore was both a summative and formative assessment—but its power arose from the fact that it was an extremely social event (approximately 180 students all marking a piece of work at once, and all seeing the result immediately after everyone has clicked). Furthermore, from focus groups ran on other courses, we find testimonies of powerful effects when students compare the mark they themselves have awarded and the average mark awarded by the group as a whole.

For instance, at a focus group we ran with Masters' students in 2012 where live evaluation with clickers was used in true peer-assessment (actually evaluating fellow students' work not that of previous cohorts), students talked about adjusting subsequent marking (for instance, make it more lenient) based on how the class as a whole had marked compared to their own.

> now I don't know whether sometimes, I felt if I gave maybe a low mark and I saw the class gave a high mark that may alter my opinion for the subsequent question they deserve a bit more because they, I don't know, maybe I am underestimating the site—that's what everyone else thinks, (Focus Group with Masters' Students May 2012)

6 Discussion

We believe the use of live evaluation of exemplars has demonstrated real benefits in our course. Of course the validity and reliability of these findings has to be placed in the context of the aforementioned factors that might have also contributed to higher student attainment (variability of cohort, teaching materials and rubrics). Nonetheless, the year-on-year improvement in the final CV score is striking.

For these kinds of approaches to be applied more widely, attention needs to be paid to the following three requirements.

6.1 Clicker Technology

During our interventions the application Turning Point with its various hardware clickers was used, though recently a number of mobile apps have appeared for live polling.

6.2 Type of Artefact Being Evaluated

Some kinds of academic artefacts are easier to evaluate than others. A multimedia CV like the ones we have covered here requires only a few minutes to fully cover all its screens with some commentary. A poster might require even less—similarly a lab report. Something however like a large project report might require a lot of advanced notice—and the danger of running evaluation sessions for them is that not all the students are sufficiently prepared (that is to say, they haven't actually read the reports).

6.3 Change of Mindset

Finally, a change of academic mindset might be necessary. To allow ones' own judgements to be publicly contested also requires a level of confidence in those judgements as well as a pluralistic orientation to recognize they may not be the only ones. The kind of mindset required is brilliantly described by Anna Stetsenko (2009):

> Therefore, from the transformative activist stance, the error is not in teaching tied to ideals and ideologies, but in demanding that students share positions that teachers advocate instead of teachers engaging in an open-ended dialogue with disparate visions, with students bringing in their own beliefs and commitments to all discussions and inquiries. In other words, the error is in elevating teacher's ideology and agenda as the pre-established and immutable frame not amenable to change instead of bringing this agenda and agendas of students to light and critically interrogating them all while negotiating points of agreements and conflicts. (p. 15)

7 Conclusion

Chickering and Gamson (1987) choose "communicates high expectations"; as one of the seven principles for good practice in undergraduate education. The use of exemplars has been reported in a number of studies as being and effective way to achieve this. However, this typically takes place in small group situation involving discussion between tutors and students and is labor and resource intensive. We believe the techniques we have shown here, involving 2 h of full class involvement in evaluating previous cohorts work using EVS, offers a way of very efficiently communicating these expectations to a very large cohort. Grading participation in evaluation event appears important to achieve full cohort coverage but doing so based on marking style raises opposition among the students (though it does not seem to alter the efficacy of the procedure). Therefore, having an evaluation event involving both the subjective evaluation of exemplars as well as some objective test on the properties or techniques used in those exemplars appears the best way to satisfy the goal of full cohort engagement with assignment marking criteria. Marking previous work together with students enables them to concretize those criteria in specific examples, thus making those criteria actionable and radically transparent

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Chapter 12
Assessing the Level of Collaborative Writing in a Wiki-Based Environment: A Case Study in Teacher Education

Said Hadjerrouit

Abstract Wikis have received the last few years a growing interest as tools for supporting collaborative writing in teacher education. This paper reports on results from a case study that aimed at assessing the level of collaborative writing among teacher students. Taking advantages of wiki affordances, the proposed theoretical framework uses a taxonomy of category actions that can be carried out on wiki. These provide a powerful instrument to analyze students' individual contributions to the wiki and level of collaborative writing among students as well. Implications for teacher preparation and professional development are drawn from the results and future research actions are envisaged to enhance the quality of wiki-based collaborative writing in teacher education.

Keywords Collaboration • Collaborative learning • Collaborative writing • Cooperation • MediaWiki • Teacher education

1 Introduction

Wiki was invented by Ward Cunningham in 1994 to enable users to communicate easier and to write documents collaboratively, using a simple mark-up language and a Web browser (Leuf & Cuningham, 2001). Recently, wikis have been promoted as collaborative writing tools in educational settings. A large body of research exits on wikis and their effect on collaborative writing in teacher education. The research literature reports on a number of studies, such as online coursework, teacher evaluation, class project, joint article, digital stories, and many other application examples (Austin et al., 2010; Deters, Cuthrell, & Stapleton, 2010; Chao & Lo, 2011; Every, Garcia, & Young, 2010; Mindel & Verma, 2006; Parker & Chao, 2007;

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Witney & Smallbone, 2011). However, despite studies reporting on positive experiences, there are still problems and barriers that prevent students from fully collaborating, such as lack of unfamiliarity with wikis, dominant learning paradigm, limited student contribution, problem of ownership, and lack of an appropriate pedagogy, etc. (Karasavvidis, 2010; O'Bannon, Lubke, & Britt, 2013; Poyas, 2013).

The main goal of this work is to use a theoretical framework to assess the level of students' collaborative writing in teacher education by means of MediaWiki. The framework describes the concepts of collaborative learning and writing, and makes a clear distinction cooperation and collaboration. It presents a taxonomy of category actions that can be carried out on wikis, and types of comments that can be posted on the discussion page of the wiki. The article uses the history log to assess the level of work distribution, the types of actions carried out on the wiki, and timing of contribution. In addition, the article also categorizes the students' comments posted on the discussion page by increased level of collaboration. Pedagogical implications are drawn from the results. Future research directions are also envisaged to enhance collaborative writing in teacher education.

2 Theoretical Framework

2.1 Collaborative Learning and Writing

Collaborative learning is a process generated by groups of students working together as a team. It creates a social learning environment that is more fruitful than the addition of individual work (Thompson & Ku, 2006). The advantages of collaborative learning are underpinned by sociocultural learning theory that assumes that learning occurs through information sharing, discussion, and interaction (Vygotsky, 1978). The learning benefits resulting from collaborative learning are supposed to be greater than the sum of individual work (Witney & Smallbone, 2011; Yarrow & Topping, 2001). As a result, students "can achieve more collectively than individuals in terms of learning outcomes" (Witney & Smallbone, 2011, p. 102).

Collaborative writing is a form of collaborative learning, and refers to written work that is created by multiple people collaboratively rather than individually. In other words, collaborative writing is an activity that transforms a written text into a collective document (Bradley, Lindström, Rystedt, & Vigmo, 2010; Chao & Lo, 2011; Trentin, 2008). Yarrow and Topping (2001) claim that students writing collaboratively improved significantly more than those who wrote alone. According to McConnell (2006, cited in Bradley et al., 2010), collaborative writing fosters critical thinking, information sharing, discussion, and communication. Collaborative writing also enables students to practice literature review, academic reading and writing (Kim, Hong, Bonk & Lim, 2011; Trentin, 2008).

Finally, collaboration as a mode of work must be distinguished from cooperation. In education, cooperation is defined as the division of work between students who are faced with a joint activity, while collaboration involves the "mutual engagement of participants in a coordinated effort to solve the problem" (Dillenbourg, Baker, Blaye, & O'Malley, 1996, p. 190, cited in Judd, Kennedy, & Cropper, 2010). Likewise, in a collaborative writing environment, students coordinate their efforts to accomplish a writing task collectively (Resta & Laferriere, 2007). In contrast, cooperative writing is seen as work where participants split a task into subtasks among themselves, and work independently from each other.

2.2 Wiki as a Collaboration Tool

From a technological point of view, wiki tools are supposed to have a user-friendly and intuitive user interface that does not require much training (Lamb, 2004; Tetard, Patokorpi, & Packalen, 2009). In addition, wikis have three important features that are useful for collaborative writing (Roussinos & Jimoyiannis, 2013). Firstly, web editing to quickly create, modify, delete, or change content via a Web browser using a simplified HTML language. Secondly, wikis have a discussion page for written communication and reflection. Thirdly, wikis have a history function (or log) that tracks all students' activities and actions carried out on the wiki. MediaWiki is seen as one of the most appropriate wiki tools for collaborative writing in teacher education. In contrast to open source wiki software, MediaWiki is restricted to university employees and students, making it particularly appropriate for education (Kasemvilas & Olfman, 2009). MediaWiki provides functionality to perform collaborative writing activities, e.g., editing content and tracking students' contributions. Data are stored in the history log, enabling teachers to assess the distribution of work among students and the types of activities carried out on the wiki. MediaWiki has also a page that supports written communication, discussion, and negotiations. As such, MediaWiki is supposed to stimulate students to collaborate, share knowledge, communicate, and interact with each other to reach a common goal (Chu, Kennedy, & Mak, 2009).

2.3 Wikis in Teacher Education

Wikis emerged the last few years as a mainstream collaborative writing tool in teacher education. Wikis can be used to support technology integration, online courseware, pedagogical instruction, and project-based learning in teacher education programs and courses. Wikis can be used collaboratively by students for a joint project or assignment, essay or article, and many other applications (Biasutti & EL-Deghaidy, 2015; O'Bannon et al., 2013; O'Bannon & Britt, 2011; Poyas, 2013). Collaborative writing can also benefit from peers' assessment and feedback (Peled, Bar-Shalom, & Sharon, 2014).

The main features of wikis mentioned above, that is web editing, history log, and discussion forum, are potentially powerful instruments in teacher education. Wiki editing features allow students to develop and synthetize content associated with a specific topic in teacher education. Wikis can incorporate content from textbooks and online study material, for example links to information on Wikipedia and external Websites, and content in multimedia form as well. As such, wikis can be used to support all educational levels in teacher education and specific parts of a given subject. Because of their simplicity and ease-of-use, wikis allow users to focus on the content and learning task, and pedagogical considerations as well (O'Bannon et al., 2013). The pedagogical dimension is important for many reasons. It may stimulate students to engage in collaborative learning. It may motivate them to collaboratively create and critically discuss a content that can be evaluated in terms of pedagogical criteria. Finally, it may challenge students to take into account the characteristics of the target users.

The history log that keeps track of wiki pages created by users is a powerful tool in teacher education. It enables users to make content revision, compare different versions of the wiki, and revert to earlier versions of the wiki if necessary. In addition, the history log is an inherently valuable source of information for the teacher (Judd, Kennedy, & Cropper, 2010). It helps to analyze the content and create statistical data on students' contributions to the wiki.

The discussion page enables information exchange and written communication. It may stimulate students' discussions, reflections, negotiations, and revisions of the wiki content. Using the discussion page to promote communication as a form of collaborative learning may have great potential in teacher education.

As a result, wiki-based collaborative writing in teacher education emerges from the interactions of wiki editing functions, discussion forum, and history log, on the one hand, and collaborative learning and writing, on the other hand (Hadjerrouit, 2013a).

2.4 Wiki Actions

Students in teacher education can make various contributions to a wiki: add new information, remove content, restructure existing content, or revise the meaning of sentences, etc. Until recently, there have not been methods that would help in categorizing these various wiki editing types. Recent studies, however, have provided guidance to classify activities performed on wikis. Pfeil, Zaphiris, and Ang (2006) used a taxonomy to categorize editorial types in Wikipedia, which was later adapted to wikis by Meishar-Tal and Gorsky (2010). The taxonomy used in this paper draws on this research (Meishar-Tal and Gorsky (2010), pp. 101), which originally included 13 categories, of which the following 10 were identified as important to assess collaborative writing (see Fig. 12.1).

Three categories were not considered in this work. The first category was "Vandalism," because MediaWiki, unlike Wikipedia, is restricted to university users, and, therefore, there is almost no risk to demolish pages. The second category was "Mark-up Language" that may change the appearance of pages. This was not included, because the HTML code being used is simplified and does not impact the

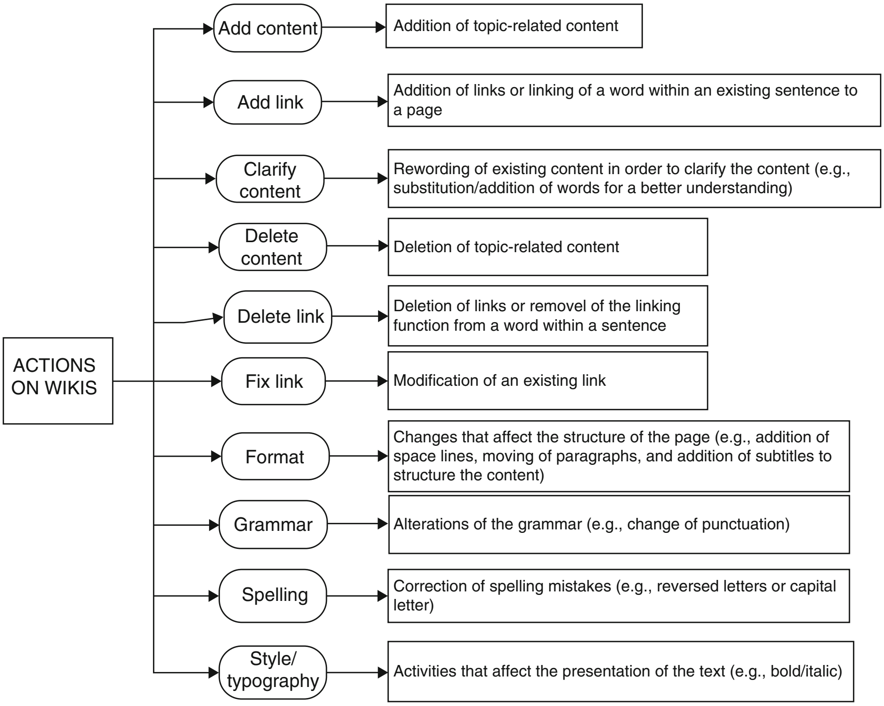


Fig. 12.1 Taxonomy of category actions

content. The last category was "Reversion," that is reversion of a page to a former version in order to reverse vandalism or certain users' activities. The reasons for not considering "Reversion" is that the risk for vandalism is minimal, and, in addition, reversing users' activities was not recommended to avoid drastic changes of the wiki content.

Genuine collaborative writing is a matter of changing, clarifying, and reworking each other's contributions to the wiki (Hadjerrouit, 2013b). In contrast, work where participants divide the wiki task in subtasks among themselves, and develop the content independently of each other without changing the content produced by peers, cannot be considered as genuine collaboration (Hadjerrouit, 2013b).

These categories have not the same level of importance when it comes to assess collaborative writing. To examine the level of collaboration, these categories need to be divided into three main groups of actions:

(a) Actions associated with technical issues, such as presentation, appearance, and structure of the wiki (format, style/typography)
(b) Actions on content, which do not change the meaning of sentences or links (add and delete information, add and delete link)
(c) Actions on content, which in contrast to the second group alter the meaning of sentences or links (clarify information, fix link, grammar, and spelling)

These groups of actions can be described by increased level of collaboration. The first group is characterized by a low level of collaboration, since the actions focus mostly on technical issues, without reference to content. The second group emphasizes actions on content, such as add or delete information or links, without changing the meaning of sentences. These types of actions can be considered more as cooperative than collaborative activities according to the distinction between cooperation and collaboration. But, it may happen that students make minor changes in sentences, or move sentences from one to another place in the wiki. Thus, this group of actions can be characterized by a middle level of collaboration. Finally the highest level of collaboration is achieved when students alter, rework, or revise the meaning of sentences substantially, fix links, and correct the grammar and spelling. This is the case of the third group.

3 Literature Review

Research studies report both on positive and negative experiences with wikis, using mostly survey questionnaire and interviews, or similar methods. Few studies are based on the history log, which is inherently more reliable when reporting on students' contributions to wiki in terms of level of collaboration among students, type of actions carried out the wiki, work distribution, and other quantitative data (Chu, Lee, & King, 2012; Hadjerrouit, 2014; Judd, Kennedy, & Cropper, 2010; Leung & Chu, 2009).

On the positive side, Thomas, King, and Minocha (2009) reported that the students felt that a wiki is a good medium for collaborative work in a distance-learning course. Likewise, Minocha and Thomas (2007, p. 310) reported that "the use of simple wiki … did support the socioconstructivist pedagogy," and that "all the groups completed their collaborative activities." Nevertheless, they suggested that wiki alone may not be sufficient "to be fully effective in realizing all the potential benefits of collaborative activities" (Minocha and Thomas (2007, p. 310)). More recent studies also reported on positive use of wikis in teacher education (Biasutti & EL-Deghaidy, 2015; O'Bannon & Britt, 2011; Roussinos & Jimoyiannis, 2013).

The literature research also reports on lack of collaboration, strong presence of face-to-face, technical and pedagogical problems, and challenges as well. Research has raised a number of shortcomings regarding the technical capabilities of wikis, e.g., the lack of a WYSIWYG editor that facilitates editing (Thomas et al., 2009). Likewise, Harsell (2010) indicated that students still stress the need for technical training, because they do not possess prerequisite knowledge for using wikis. Similarly, Jones (2010) pointed out that technical problems still constitute sources of frustration for some students.

In addition, Huang and Nakazawa (2010) argued that learners are not accustomed to the wiki way of collaboration. Therefore, teachers need to sustain learners' wiki activities throughout a learning process. Likewise, researchers pointed out that students use wiki more co-operatively than collaboratively, by dividing up the tasks at the outset and then later assembling the separate parts of the tasks (Tay & Allen, 2011; Witney & Smallbone, 2011). Similarly, a number of research studies seem to confirm that students appear to favor individual work over collaboration using wikis. Elgort, Smith, and Toland (2008) indicated that a significant number of students believed that they could have done the work better on their own without collaborating with others. Cole (2009) reported that after 5 weeks, the students had not contributed to the wiki at all. Similarly, Ebner, Kikckmeier-Rust, and Holzinger (2008) indicated that none of the 287 students involved in wiki created new pages or edited existing pages over the whole semester. Also Grant (2009) found that collaborative practices are not evident when using wiki. Rather, students seemed to import practices of individualized written assessment. Other challenging aspects of collaboration are the purpose and nature of collaboration, the different levels of interaction, and competition in collaborative learning (Austin et al., 2010).

Furthermore, Witney and Smallbone (2011) reported that face-to-face communication was the students' preferred means of facilitating group work and discussion. In addition to oral communication, students also use other tools (email, Google Docs, Skype, mobile phone, etc.) in combination with wikis when they process collaborative activities. As a result, Huang and Nakazawa (2010) suggest limiting students' access to other tools as a prerequisite to create an authentic wiki-based learning environment.

Another critical aspect is that students need to be given more time to familiarize themselves with wikis, because collaboration among students is demanding and time-consuming (Caple & Bogle, 2013). Likewise, assessment is important to evaluate students' individual contributions to collaborative writing (Tetard et al., 2009). Furthermore, Caple and Bogle (2013) pointed out that wikis need to be customised to the specific needs of the users, as part of a virtual community, where members have access to the wiki.

Finally, researchers suggest that it is the pedagogical approach to wiki that leads to collaboration, not the technology itself (Cole, 2009; Tay & Allen, 2011; Witney & Smallbone, 2011). Karasavvidis (2010, p. 226) argues that most problems experienced by the students with wikis hint at a "fundamental problem, namely the dominant traditional practices and the associated learning epistemology which is compatible by such practices."

4 Methodology

4.1 Aim and Research Questions

This work is a case study in teacher education. It provides a suitable context to explore wiki technology in relation to collaborative writing. The study aims at assessing the level of teacher students' collaborative writing by means of MediaWiki.

On the basis of the results, pedagogical implications are suggested. The work addresses four research questions:

(a) What is the level of work distribution among the student groups?
(b) What are the categories of actions carried out on the wikis?
(c) What are the types of comments posted on the discussion page?
(d) What is the timing of contribution of each student group?

4.2 Participants

Data came from 16 teacher students ($N = 16$) enrolled in a course on Web 2.0 technologies in teacher education in 2012. The participants were divided into six groups of two to four students. All students had experience with working in groups, but none of the participants had any prior experience with collaborative writing or with wiki as a learning environment for collaborative writing. There were nine (56.25 %) full-time students, and seven (43.75 %) part-time students. All have been introduced to Web 2.0 technologies, such as blogs, Twitter, Google Docs, Facebook, Second Life, etc. Some of the students possessed basic knowledge and skills in HTML coding and Web design, e.g., uploading files and images, using multimedia and animations. Most of them have background in teacher education.

4.3 Purpose, Content, and Assessment

The purpose of this study is to engage students in collaborative writing activities with MediaWiki. The wiki content of the respective student groups included teacher education subjects such as geography, history, mathematics, and science. The teacher provided a set of assessment requirements. First, the wikis should follow general usability criteria such as technical layout, text organization, paragraph structure with heading and subheading. The wikis should contain links, images, tables, lists, and references. Second, the wiki should provide quality information, without linguistic, grammatical, and spelling errors. The content should draw on recent curricular development in teacher education, and include study material and topics that are of interest for students. Third, the wiki content should be self-explaining, and offer information that is relevant and adapted to the characteristics of the users. Given these requirements, the students were encouraged to collaborate by editing each other's work, and take part actively in discussions by reflecting on wiki-related issues. The student groups were required to deliver wikis with a minimum of 4000 words to ensure that a sufficient quantity of writing can be produced. Fourth, to enhance the quality of the wikis, the students were required to assess each other's wikis by providing constructive peer feedback. Finally, the students were assessed a as a group creating a collective wiki, and not individually according to the amount of work they produced.

4.4 Data Collection and Analysis Methods

The main data collection method was the history log that tracks all students' actions carried out on the wikis. Data found in the log was analyzed in terms of the category actions described in the theoretical framework, that is add and delete content; add, fix, and delete links; format, correct grammar and spelling mistakes, and clarify content. In addition, the analysis of the comments posted on discussion log was used as a supplementary method.

The data collected by means of the history log were examined through a combination of three methods:

(a) The level of work distribution among members of the groups.
(b) The total number of actions per group and category, including their frequencies, such as whether the action was an addition, deletion, or clarification of information; addition, deletion, or fixation of a link; format, spelling, style, or grammar, etc.
(c) Work intervals or timing of contribution to assess how students worked over a period of 2 months (8 weeks) from January 15 to March 15.

The history log provides in-depth information about the types of actions that are carried out on the wiki and helps to assess collaborative writing in terms of work distribution and timing of contribution. More specifically, the log allows the investigation of students' activities in terms of actions carried out on the wiki across the categories of the taxonomy described above.

The students' comments posted on the discussion page were grouped and analyzed according to three main categories of comments:

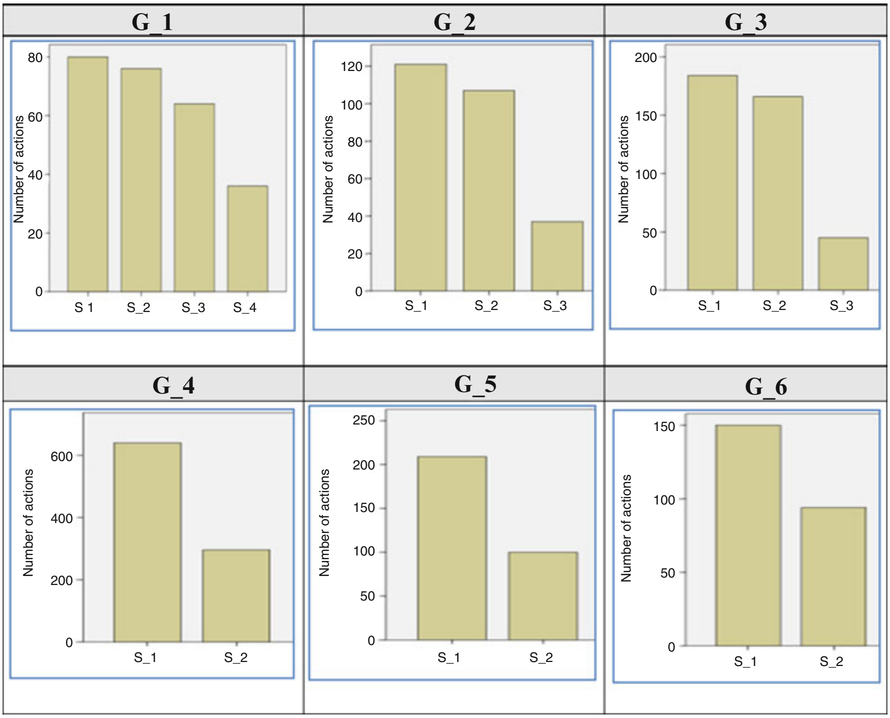
(a) Comments associated with technical issues
(b) Comments on content, which do not change the meaning of sentences or links
(c) Comments on content, which in contrast to the second group, alter the meaning of sentences or links

5 Results

5.1 Analysis of Actions in the History Log

Table 12.1 presents the level of work distribution made by each student (S_1, S_2, S_3, S_4) in the respective groups (G_1, G_2, G_3, G_4, G_5, G_6) in terms of the number of actions carried out on the wikis. The table shows that the workload of the groups was not equally distributed between all members. In groups of two students (G_4, G_5 and G_6), the results indicate that one member of the groups assumed nearly 68–61 % of the workload, while the other students contributed to 38–32 %. In groups of three students (G_2 and G_3), two members (S_1 and S_2) assumed more than 85 % of the workload, while S_3 contributed to only 11–14 %. Finally, in the

Table 12.1 Distribution of work among members of each group in terms of the number of actions



group of four students (G_1), the results show that three students (S_1, S_2, and S_3) did most of the work (86 %), while S_4 contributed only to 14 %. The results reveal that there is a huge variation in terms of the number of actions among the best students in the groups ranging from 640 (S_1 in G_4) to 80 (S_1 in G_1).

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The analysis of work distribution does not reveal the extent to which students collaborated to create the wikis. A categorization of actions is therefore necessary to analyze the level of collaboration.

Figure 12.2 shows the number and percentage of actions that fell under each of the 10 categories investigated. The table reveals that the most common category of

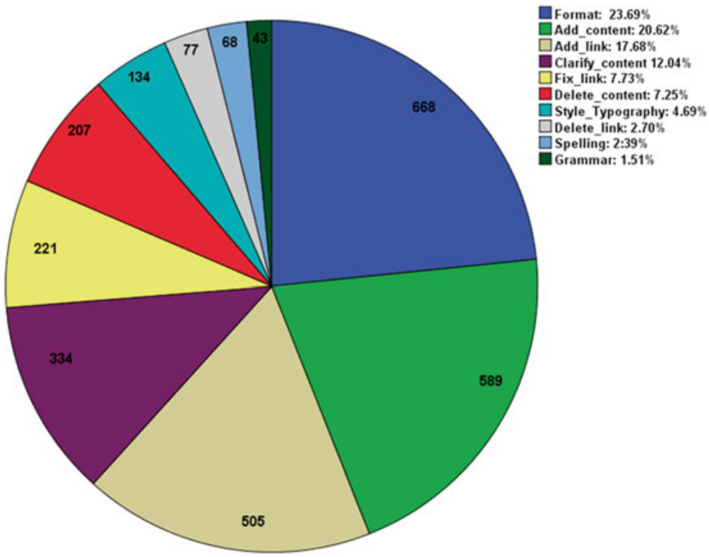

Fig. 12.2 Category of actions in terms of the number of actions and percentage of total

action was format (668 actions, 23.69 % of all actions), followed by addition of content (589, 20.62 %), addition of links (505, 17.68 %), clarification of content (334, 12.04 %), fixing of links (221, 7.73 %), deletion of content (207, 7.25 %), style/typography (134, 4.69 %), deletion of links (77, 2.70 %), spelling (68, 2.39 %), and finally, grammar being the last common category action (43, 1.51 %). Note that a single edit may involve several actions, such as add content, delete a link, clarify content, or correct spelling mistakes.

Figure 12.3 shows the timing of contribution of each group of students in terms of the number of actions per week. The results show that all groups worked much as the deadline for submitting their work approached (March, 15), except for group 6. This is reflected in the average number of actions per week carried out on the wikis.

5.2 Analysis of Comments Posted on the Discussion Log

A detailed analysis of the comments posted on the discussion page shows that the students made comments on a range of issues. Following Su and Beaumont (2010), the content of the comments were analyzed and categorized by increased level of collaboration:

- Comments on technical issues of the wiki (low level of collaboration)
- Comments on wiki content (middle level of collaboration)
- Comments on collaborative writing (high level of collaboration)

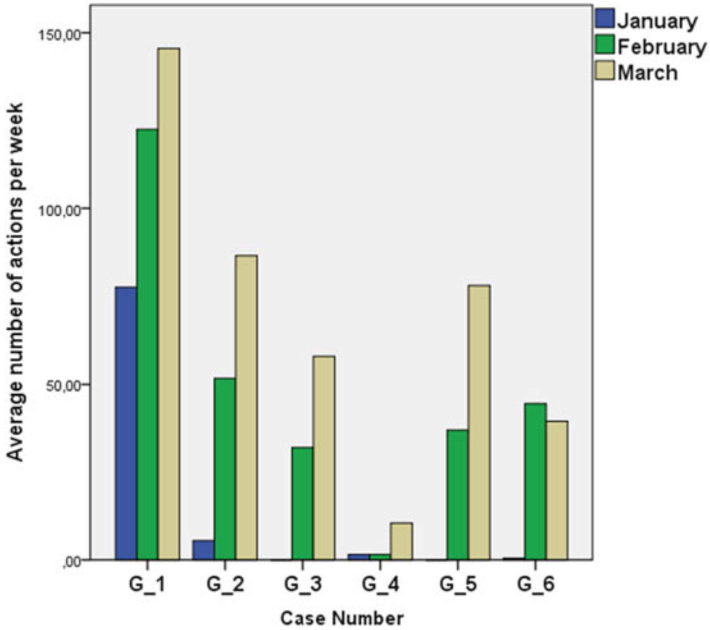

Fig. 12.3 Timing of contribution in terms of the number of actions per week

The lowest level of collaboration is characterized by a discussion of technical issues such as layout, structure, placing of images and figures, inserting tables and lists, format, and typography, with almost no reference to the wiki content.

The middle level of collaboration is achieved when students discuss the wiki content in terms of addition or deletion of content, proof reading and grammar corrections, references, navigation and linking of keywords, and wiki length. These actions do not change the meaning of sentences or text.

The highest level of collaboration involves students critically discussing the relevance of the wiki content, and identifying gaps in their knowledge. Equally important are the review of the literature, adaptation of language to the target audience, clarification, and revision of the content. In contrast to the middle level of collaboration, these actions alter the meaning of sentences.

As Table 12.2 shows, most comments were those with a low level collaboration (55.21 %). These comments referred, in ascending order, to images (34 occurrences), format (25), tables (23), typography/style, pages, and subpages (15), and lists (7).

Middle level collaboration comments (38.54 %) related to addition of information (24), links (22), wiki length (13), references (5), proof reading and spelling errors (5), keywords to be linked (3), and categories (2).

There were few comments with a high level of collaboration (6.25 %). These referred mostly to wiki requirements (8), and collaboration (4). Issues such as use-

Table 12.2 Distribution of comments in each category posted on the wikis

Level of collaboration	Category of comment	Number of comments	Frequency of comments (%)
Low	Technical issues, e.g., page structure, format, images, tables, lists, paragraphs, headings	106	55.21
Middle	Structure of content, linking, keywords, wiki length, proof reading, grammar and spelling errors, references	74	38.54
High	Relevance and quality of content, wiki requirements, literature review, adaption of language to target audience, clarification and revision of content	12	6.25
Total number of comments		192	100

fulness of information sources, study material being used, literature review, adaptation of language to the target audience (or potential users of the wikis), clarification and revision of content were not addressed. Only one student emphasized the need to work collaboratively.

Considering that the category of comments with a high level of collaboration is the one that requires critical reflections and discussion, it can be asserted that the overall level of collaboration was rather low. In addition, the number of comments (192) is very low compared with the number of total actions (2856), which means an average score of only one comment per 14.87 actions. Finally, a closer look at the discussion dates and time show that most comments were posted the last 2–3 weeks before the delivery of the wikis, in line with the timing of contribution. Otherwise, it was difficult to follow the discussion treads of the respective wikis, because the date of contribution or/and the name of contributor were missing.

6 Discussion

6.1 Summary of Results

A careful analysis of the history log in terms of the category actions described in the theoretical framework reveals that there is no evidence that the students truly collaborated. Instead, format, style/typography, add/delete content and links were the most actions that were carried out on the wikis. Furthermore, the workload was not equally distributed among all members of the groups. The timing of contribution also indicates that all groups worked much as the last day for submitting their wiki approached. Clearly, collaborative writing was performed on a superficial level by formatting the presentation of the wikis, adding content and links. In contrast, genuine collaborative writing by reworking each other's contributions was not a frequent activity. As a result, individual work and cooperation were more evident than collaboration. The results achieved by means of the history log are in line with the students' comments posted on the discussion log. These reveal that the level of collaborative writing among the student groups was low. The results achieved so far are in line with similar research work (Cole, 2009; Grant, 2009; Elgort et al., 2008; Hadjerrouit, 2012; Hadjerrouit, 2013b; Hadjerrouit, 2014; Judd, Kennedy, & Cropper, 2010; Karasavvidis, 2010; Neumann & Hood, 2009). These studies point out to several hypotheses in an attempt to explain the low level of collaboration when using wikis in educational settings: unfamiliarity with wikis, lack of experience, dominant learning paradigm, limited student contribution, reluctance and resistance to use wiki, lack of motivation and engagement, time management, problem of ownership, and lack of an appropriate pedagogy.

6.2 Implications for Teacher Preparation and Professional Development

The work and the results achieved so far have a number of implications for teacher preparation and professional development. Firstly, the benefits of collaborative writing are underpinned by epistemological assumptions based on Vygotsky's sociocultural theory that assumes that learning occurs through collaboration and information sharing (Vygotsky, 1978). Accordingly, collaborative learning is considered as superior to individual learning (Witney & Smallbone, 2011). However, the full potential of wikis cannot be fully realized, unless collaborative learning approaches are adopted and deployed in educational settings. In other words, collaborative writing will not work successfully unless teacher students are accustomed to collaborative practices. This cannot be achieved without changing the social practice from individual to collaborative learning, and creating new opportunities to realize shared knowledge in educational settings (Grant, 2009). One important opportunity is the students' preparation and prior acquisition of basic collaborative skills (Minocha & Thomas, 2007). Prework can give students a sense of how collaboration can be achieved by following a common goal and coordinating their efforts under the guidance of the teacher. Clearly, students should be given more time and training opportunities to familiarize themselves with collaborative practices in a wiki-based learning environment, because not all students possess sufficient prerequisite knowledge for using wikis. Hence, technical training is still needed to help students acquire the basic knowledge that is necessary to use wikis for collaborative writing.

Secondly, as collaboration and critical reflections are necessary conditions for using wikis, students should be given the opportunity to discuss the writing tasks in terms of usefulness of content, relevance of literature, and adaptation of the wikis to the users' needs. Instruction should be more comprehensive and help students firmly grasp their knowledge in order to make their wikis more attractive for the target users. They should learn to focus less on selecting content from Wikipedia and other Websites than critically discussing their ideas in collaboration. Instruction should also include some language issues to improve the quality of collaborative writing and make the writing process easier, especially for students with technical background, without an adequate level of language proficiency (Li & Zhu, 2013). Furthermore, student groups need to be knowledgeable in the topics being studied in order to create wikis of good quality with relevant references, because those lacking basic knowledge in the topic being studied will not be able to truly contribute to the wiki content.

Thirdly, another pedagogical implication is that assessment can play an important role in evaluating students' contributions to the wiki. The assessment procedure being used in this work has indeed influenced the way students collaborated. Since students were assessed as groups, and not according to their individual contributions, it is not surprising that some students did not fully engage in collaborative writing. As a result, most of the work was done by some students as the distribution of work clearly reveals. It is also possible that some students were more dominant than others (Meishar-Tal & Gorsky, 2010). Clearly, collaborative writing requires more than group assessment, because it may be necessary to judge individual contributions, which in turn, may influence positively, students' contributions to collaborative writing. Assessment forms may be self-assessment or/and peer-assessment on an individual basis or in groups. Peer feedback is particularly important in a wiki-based environment, because it helps students to learn to be critical assessors (Peled, Bar-Shalom, & Sharon, 2014). Also the close integration of learning goals and assessment goals, and how the content will be assessed, and which assessment forms are used, may motivate students to effectively engage in meaningful collaborative writing (Hadjerrouit, 2013b). In this regard, motivation is an essential component of collaborative writing, and must be seen in relation to the wiki content itself, whether it is intrinsically interesting, highly relevant, and meaningful to the students. To be effective, assessment of students' contributions to the wikis should be mandatory, and based on pre-established quality criteria.

Furthermore, the process of creating wikis needs to be carefully planned by teachers to guide and sustain students' collaborative writing activities. In addition to management and planning activities, wiki-based collaborative writing cannot be successful without a sound pedagogy based on collaborative learning or similar learning paradigms such as the sociocultural approach to learning (Vygotsky, 1978). A pedagogical strategy that supports genuine collaborative writing should engage students in collaborative work and group dynamics to a greater benefit of the students.

Finally, wikis as a type of social software can stimulate students to communicate their ideas better than using another technology. However, students need to be aware of the added value of wikis in terms of collaborative capabilities compared to other communication systems. They also need to critically judge the limitations of wikis when communicating with each other. As the wiki discussion page in its present form is not the ideal arena through which to reflect ideas, teachers and students still need face-to-face meetings and oral communication by means of other channels, e.g., mobile phone and email, or in conjunction with similar ways of collaborating, including social software such as Facebook and Blogs. Another reason is the lack of comfort when communicating online with someone the students do not know (O'Bannon et al., 2013). As a result, a pedagogical model that combines wiki technology, face–face interactions, and social software may provide the most beneficial communication scenario for teacher students. Nevertheless, current wiki platforms should be improved to include advanced functionality that enables students to express their ideas in collaboration with peers. Clearly, the limitations of wiki technology should not disturb the flow of discussion and communication threads.

7 Future Work Directions

Two research directions are envisaged to foster collaborative writing in teacher education. Firstly, it is important to develop a wiki-based pedagogy to ensure a better use of wikis in teacher education (Cole, 2009; Hadjerrouit, 2013b; Poyas, 2013). The question, which faces researchers and educators today, is not why or whether to use wikis, but when and how, that is issues of wiki pedagogy (Walsh, 2010). In this regard, the importance of a sociocultural learning approach to wikis based on Vygotsky's ideas cannot be underestimated, since putting students together does not automatically result in collaboration. Extending wiki to include a sociocultural approach to learning requires the integration of wikis into a pedagogical strategy that supports genuine collaborative learning. A pedagogy that suits wikis can engage students in collaborative work and group dynamics to a greater benefit for all members of the groups. This approach to wikis requires a thoughtful interweaving of content, technology, and group work to the benefit of collaborative writing. In a wiki-based learning environment, students have to actively engage in design practices and inquiry as they develop their wiki. In this environment, the role of the teacher is to create an atmosphere of confidence that stimulates students to collaborate for the benefit of the groups, as well as provide specific guidance to assist them in the writing process. Ultimately, the process of creating a wiki of high quality needs to be carefully planned by teachers to sustain, manage, and motivate student participation in collaborative writing activities (Allwardt, 2011; Huang & Nakazawa, 2010).

Secondly, following the sociocultural approach to wikis, it becomes necessary to help students become more familiar with wikis and more skilled in collaborative learning and writing (Harsell, 2010). Indeed, a critical factor of success is the students' preparation for collaborative writing, and familiarization activities with wikis (Minocha & Thomas, 2007). In the networked society that is grounded on team work, training in collaborative learning and acquisition of collaborative skills cannot be restricted to wikis alone, but should be possible using appropriate methods, such as allow students with different backgrounds discuss and integrate different aspects of a topic-related content or develop mutual understanding of complex issues of the topic, and thereby add to each other's knowledge. Another way to foster collaborative learning may be the discussion of students' summaries through the study of wiki-related topics (Tetard et al., 2009). Group-based tasks and similar work may provide opportunities for wiki-based collaborative learning and writing. But still, it is likely that students will need constructive feedback and guidance in seeing collaborative learning as a part of their work (Wake & Modla, 2012).

8 Limitations and Conclusions

The main conclusion of this work is that wiki technology alone cannot automatically foster collaborative writing in teacher education. Even though the results cannot be generalized to all levels and subjects in teacher education, because the case study was relatively short term and was based on a small sample size ($N = 16$), it is possible to draw some pedagogical implications from the results to successfully foster wiki-based collaborative writing, including possible research directions. Likewise, the theoretical framework for evaluating the level of collaborative writing will be refined to include more action categories and comment types. In terms of data collection and analysis methods, the instruments being used to create statistical data based on the history and discussion log will be supplemented by survey questionnaire by considering specific issues associated with collaborative writing. Other methods such as focus groups and interviews may be used to ensure more reliability and validity of the results.

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Chapter 13
Student-Centered Analytics for Postsecondary Education

Timothy Arndt and Angela Guercio

Abstract Recently, organizations have begun to realize the potential value in the huge amounts of raw, constantly fluctuating data sets that they generate and, with the help of advances in storage and processing technologies, collect. This leads to the phenomenon of big data. This data may be stored in structured format in relational database systems, but may also be stored in an unstructured format. The analysis of these data sets for the discovery of meaningful patterns which can be used to make decisions is known as analytics. Analytics has been enthusiastically adopted by many colleges and universities as a tool to improve student success (by identifying situations which call for early intervention), more effectively target student recruitment efforts, best allocate institutional resources, etc. This application of analytics in higher education is often referred to as learning analytics. While students of postsecondary institutions benefit from many of these efforts, their interests do not coincide perfectly with those of the universities and colleges. In this chapter, we suggest that postsecondary students will benefit from the use of analytics which are not controlled by the institutions of higher learning—what we call DIY (Do It Yourself) analytics—a set of tools developed specifically to meet the needs and preferences of postsecondary students.

Keywords Academic analytics • Student-centered learning • Postsecondary education • Learning analytics

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1 Introduction

As noted by Kohavi et al. (2002), recently organizations have begun to realize the potential value in the huge amounts of raw, constantly fluctuating operational data sets that they generate and, with the help of advances in storage and processing technologies, collect in transactional systems. The latest techniques from computer science, mathematics, and statistics are needed to perform this analysis and generate strategic insights, e.g., about visitors to a company's website for better marketing efforts, resulting in the growing importance of the field of business analytics. It has been noted by Naone (n.d.), LaValle (2014) and in an unsigned editorial in The Economist (2011) that both structured data (stored in relational and non-relational database systems) and nonstructured data can be analyzed using data mining techniques and the results presented using information visualization methods to best guide organizations' decision-makers. Data mining is sometimes differentiated from analytics by the way that analytics tests for specific hypotheses while data mining lacks a hypothesis, instead searching large data sets for interesting patterns (see Romero and Ventura (2007), for example). Some other experts consider data mining to be a part of analytics. Siemens and Baker (2012) have highlighted the different emphases of the educational data mining research community and the learning analytics research community and have argued for increased and formal communication and collaboration between these communities in order to share research, methods, and tools for data mining and analysis in the service of developing both the LAK (Learning Analytics and Knowledge) and EDM (Educational Data Mining) fields.

Both Mattingly, Rice, and Berge (2012) and Baepler and Murdoch (2010) show that analytics has been enthusiastically adopted by many colleges and universities as a tool to improve student success (by identifying situations which call for early intervention), more effectively target student recruitment efforts, best allocate institutional resources, etc.. The evolution of big data and its widespread adoption in American higher education has been documented by Picciano (2012). Sources of the data which can be analyzed include institutional data about students, courses, and applicants; however, a particularly rich field to mine for data is associated with online courses and Course Management Systems (CMS) as noted by Romero, Ventura, and Garcia (2008). Information extracted from a CMS can be quickly assessed for early warning signs of student failure, leading to prompt intervention and increased chances of student success as well as higher student engagement. Such data can also be used for student assessment and course redesign.

Academic analytics uses a combination of institutional data, statistical analysis, and predictive modeling to create insight which students, instructors, or administrators can use to develop a strategic plan for enhancing academic outcomes. The University System of Georgia carried out an experiment using analytic techniques to develop an algorithm to predict student completion and withdrawal rates in an online environment. The results helped to confirm that it was possible to predict accurately the likelihood that a student would successfully complete an online course This is documented in Baepler and Murdoch (2010).

Fig. 13.1 SAS Visual Analytics for student enrollment (Retrieved from http://www.sas.com/software/visual-analytics/demos/student-enrollment.html)

Goldstein and Katz (2005) propose the term "academic analytics" as an alternative to "business intelligence" in the academic realm. He surveys seven areas that analytics can be used in academia: advancement/fundraising; business and financing; budget and planning; institutional research; human resources; research administration; academic affairs. The Signals project at Purdue University surveyed by Arnold (2010) has delivered early successes in academic analytics, prompting additional projects and new strategies. A visual analytic tool being used for student enrollment is shown in Fig. 13.1. Romero and Ventura (2007) provide a good overview of research in the field of educational data mining in the decade from 1995 to 2005. Clearly, most of these areas are not of interest to students in postsecondary education, except perhaps tangentially. Our DIY approach will concentrate on areas that are directly of interest to students.

1.1 *Student-Centric Approaches*

Kruse and Pongsajapan (2012) propose a student-centric, inquiry-based model of analytics that puts the tools and premises of analytics into the hands of students, empowering them as metacognitive agents of their own learning. They highlight the problematic nature of constantly viewing students as passive objects in need of "intervention" lest they "underperform" rather than as self-reflective learners given the cognitive tools to evaluate their own learning processes. Transparency in data collection is required to build student trust. The student should be aware of his own role in generating data, use that as a source of self-reflection to guide his learning process in an inquiry-guided approach. Visualization is mentioned as an attractive way to present learning data.

Kumar, Somasundaram, Boulanger, Seanosky, and Vilela (2015) developed a sensor-based big data software platform that is open, inclusive, adaptable, and precise. As part of the premises of their approach, they relate that students are welcome to relate different data sets (data are collected in the background with the students' explicit permission) to arrive at insightful analytics. The data sets and analytics techniques thereof are open for use by students.

2 DIY Analytics

While institutions of higher learning have increasingly relied on learning analytics, and while the use of analytics by the institutions can be of help to students (e.g., by identifying if they are at risk of failure in a course or in a program of study, and providing intervention to help them), the needs and requirements of institutions and students are not identical. As an obvious example, students have an interest in enrolling in the institution which gives them the best chance to succeed in their chosen field; however, a particular institution has an interest in getting that student to enroll, even if there is some other university which would better meet the student's needs. We see DIY analytics as a particular, personalized type of student-centered analytics.

Piety, Hickey, and Bishop (2014) have developed a conceptual framework for organizing emerging analytic activities involving educational data that can fall under broad and often loosely defined categories, including Academic/Institutional Analytics, Learning Analytics/ Educational Data Mining, Learner Analytics/ Personalization, and Systemic Instructional Improvement. Each distinct movement has emerged around the use of data education. They propose that a broader notion of "Educational Data Sciences" be introduced in order to benefit both those producing and consuming information from these practices as well as those developing education programs aimed at building the human capital necessary to work with educational data. The area they classify as learner analytics aims to support a personalized approach to learning based on differences among learners with regard to cognitive traits like aptitudes, cognitive styles, prior learning, and the like, as well as noncognitive characteristics such as differences in levels of academic motivation, attitudes towards content, and family situations.

2.1 Challenges

Implementing student-centered analytics will face a number of difficult challenges. Consider the following examples of divergent interests for institutions and the students enrolled in the institution. Students would like (all else being equal) to enroll in classes taught by professors that give them the best chance of achieving their goals. Institutions (colleges, departments) don't have any interest in steering students towards particular instructors and away from others. On the contrary, the department's interests are best served by having level enrollments in all sections of courses, rather than having some very large sections and other very small ones. Another example is in the choice of a field of study within an institution. The student's needs to discover the best program for him or her might not coincide exactly with those of the institution, which might want to steer students towards favored programs or away from others which might be getting too large.

In all of these cases, we propose the introduction of what we call DIY (Do It Yourself) Analytics for students. The name refers to the fact that the student himself will be using the analytics tools to make his best choices, rather than relying on the institutional filter (the DIY name is not meant to suggest that students will be creating/programming these tools themselves, only that they will be the end users). Student-centric learning analytics tools should be developed to allow students to reach their academic potential. The goal of this research is to empower students and allow them to actively control their own learning and education rather than being passive receptacle of knowledge to be filled by faceless educators. We also wish to emphasize the need for transparency in data collection so that students understand exactly what type of data about them is being generated and collected and have recourse to means to correct data which is faulty.

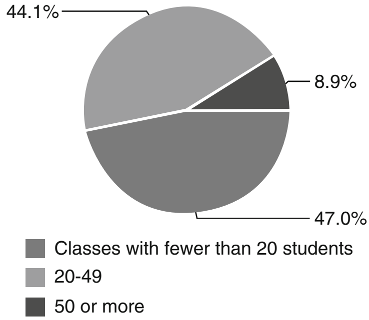
We have identified in the above scenarios several types of insights that students would find valuable in the course of their academic careers, but these just scratch the surface. There are many more possibilities that can and should be explored. We will be expanding the list of possible topics in future research.

One issue that arises immediately is—where will the information that will be the input to the analytics process come from? In organizations, this is not a problem, since the organizations own the data that they generate. The situation is different in this case however, since the students do not generate or own the data that they need for DIY Analytics to work. The institutions of higher education could make this information publicly available so that it could be used by students (after it has been suitably scrubbed to make sure that privacy concerns are met). If the institutions are unwilling to make the information available, they may need to be encouraged to do so (by government agencies in the case of publicly funded universities, by donors or accreditation boards in the case of private institutions). Some of this information is already publicly available (sometimes due to government regulations) either individually at the institutions, or collected by agencies or commercial entities (see Fig. 13.2, with information about American universities collected by US News and World Report). The Predictive Analytics Reporting Framework (PAR) project reported by Ice et al.

Academic Life

The student-faculty ratio at Kent State University is 21:1, and the school has 47 percent of its classes with fewer than 20 students. The most popular majors at Kent State University include: Business, Management, Marketing, and Related Support Service; Health Professions and Related Programs; Communication, Journalism, and Related Programs; Education; and Psychology. The average freshman retention rate, an indicator of student satisfaction, is 77.3 percent.

Class sizes



Student-faculty ratio	21:1
4-year graduation rate	28%

Five most popular majors for 2012 graduates

Business, Management, Marketing, and Related Support Services	19%
Health Professions and Related Programs	15%
Communication, Journalism, and Related Programs	9%
Education	9%
Psychology	6%

Fig. 13.2 Information about an American institution of higher learning (Retrieved from http://colleges.usnews.rankingsandreviews.com/best-colleges/kent-state-university-3051)

(2012) has shown that multiple universities can work together to unify and aggregate their data. Such work provides hope for implementing DIY analytics.

Pardo and Siemens (2014) have identified a set of principles to help guide the discussion of ethical and privacy principles for learning analytics. They define privacy as the regulation of how personal digital information is being observed by the self or distributed to other observers, where personal digital information is taken to mean information about persons captured by any means and subsequently encoded in some digital format. Of particular interest to us is one of the principles that Pardo and Siemens identify—student control over data. This dovetails with what we are attempting to achieve in this research. The open student model (Bull & Kay, 2007) has been proposed as a way to make both the information collected during the learning analytics process as well as the models derived from that data available to students. Unfortunately, this approach has not been widely adopted. The principle of student control implies that students have the right to access and correct information obtained about them.

Another challenge to the adoption of a DIY analytics is the problem of constrained resources as addressed by Buerck and Mudigonda (2014). They recommend a bottom-up approach based on careful consideration of the functionality of existing tools rather a top-down approach. Also helpful is a multi-phased approach to the introduction of learning analytics initiatives limited to one or a few courses given current constraints, later to be scaled up based on the experience gained.

2.2 Usability Concerns

Further initial reflection on this research indicates that in order for the information to be relevant for decision-making for nonexpert users (students) this use of visual analytics will be crucial. Furthermore, given the platform preferences of today's students, the data presentation should be accessible from mobile platforms (smartphones and tablets). This idea is reflected in our future prototype system in this area, which is described in the following section.

The use of student-centered DIY analytics might be most effectively achieved in the context of a learning analytics intervention as described by Wise (2014). A learning analytics intervention is that surrounding frame of activity in which the various learning analytics tools, reports, data, etc. are put into motion. As such, it describes the context and process in which those methods are used—it is not an artifact but rather a process or orchestration of processes. The students who are using the student-centered analytics can help to guide the development of such an intervention, but it may also need to be helped along by professionals who are experienced in pedagogical methods. Three core processes of learning analytic intervention are Grounding, Goal-Setting, and Reflection, while the four principles are Integration, Agency, Reference Frame, and Dialog. Empirical work can help to further develop a model based on these concepts and integrating student developed goals as fundamental.

Hu et al. (2014) describe an interesting experiment in learning analytics data exploration through a linked-data-driven web portal which allows users to browse linked data sets an explore data about researchers, conferences, and publications in the field of learning analytics. This portal could be used to glean data required for interinstitutional analysis as well as be used an exemplar of visualization techniques for learning analytics.

Visualization is an especially useful technique for casual users such as the students we envision using our DIY analytics tools. Several authors have explored visualization in the learning analytics field including Leony, Pardo, de la Fuente Valentín, de Castro, and Kloos (2012), Duval (2011), and Macfadyen and Dawson (2012). As noted by Leony et al. (2012), visualization of learning analytics data needs to take into account aspects such as how to access and protect personal data, filter management, multiuser support, and availability. Based on these considerations, they developed the web-based visualization platform GLASS (Gradient's Learning Analytics System). The architecture of the tool had been conceived to support a large number of modular visualizations derived from a common data set containing a large number of recorded events. Duval (2011) presents work on learning analytics that relies on attention metadata for visualization and recommendation. The work emphasizes goal-oriented visualizations in order to help to realize a more learner-driven approach to education, training, and learning in general. These visualizations employ a "dashboard" approach to visualizations for learning that enable a learner or teacher to obtain an overview of their own efforts and of those of the (other) learners.

2.3 Modelling Student-Centered Analytics

Why the need for DIY analytics? Don't the institutions use learning analytics to advance the needs of students? Our argument is that while the use of analytics by universities may (possibly often) advance the needs of students, this is not always the case as the goals of institutions and students are not necessarily equivalent. Furthermore, as pointed out by Kruse and Pongsajapan (2012), the ways that institutions use analytics treats students as passive subjects rather than as self-reflective learners. Further, the collection of data is seldom transparent, and the analytics tools themselves are developed for professionals rather than for the casual user—students in this case. All of these concerns need to be answered to arrive at student-centered DIY analytics.

We may model the use of learning analytics by an entity starting with a set of goals $G = \{g_1, g_2, \ldots, g_n\}$. Each goal g_i is assigned a weigh w_i by the entity which reflects the relative importance of the goal to the entity. The sum of the weights is equal to 1: $\sum w_i = 1$. Now if G_1 are the goals of the institution and G_2 are the goals of some student, then we will likely have $G_1 \cap G_2 \neq \varnothing$ (hopefully, we will not have $G_1 \cup G_2 = \varnothing$!). And even if the two sets of goals are equivalent, it is unlikely that the weights w_i will be equal for the two entities. Notice that this divergence of goals is true even among two different students S_i and S_j they will have different sets of goals G_i and G_j so DIY analytics will need to be personalized for each student.

In modeling student-centered analytics, we should also capture the social networks and social media that are of increasing importance for today's postsecondary students (Arndt & Guercio, 2013). As Gruzd, Haythornthwaite, Paulin, Absar, and Huggett (2014) highlight, social media are beginning to affect how we teach and learn in this increasingly interconnected and information-rich world. We need to determine and evaluate measures which can help educators manage their use of social media for teaching and learning through the use of automated analysis of social media texts and networks.

3 Conclusions and Future Research

This chapter has described our ideas on student-centered DIY Analytics. We have identified several scenarios where the interests of institutions of higher education and their students diverge, leading to an opportunity to add value for students. We have also identified a possible problem in the implementation of this idea—the lack of ownership by the students of the data involved, though we hope to be able to overcome this problem in the short term by scraping publicly available data off of university websites (along with government agency and other organization sites) and in the medium and long term through a more open access to institutions' data (scrubbed for privacy). Further, we have identified a few areas that DIY Analytics must address, based on the target audience. We have also sketched a preliminary model of learning analytics goals to demonstrate the alignment, or lack thereof, of goals between institutions of postsecondary education and the students these institutions exist to serve. We continue to refine all of these ideas.

We are currently in the initial stage of developing a prototype system in DIY Analytics. Our prototype will allow prospective students to explore various programs at multiple universities. The system will use SAS solutions for Hadoop documented on the SAS Solutions for Hadoop web page (http://www.sas.com/en_us/software/sas-hadoop.html). SAS Visual Analytics and SAS Mobile BI will be used to produce an application accessible from mobile devices to meet the needs of today's students. Interviews with current university students will be used as part of the design process of this prototype, and it will be evaluated by experiments with a group of target users. These results will be reported in a future work.

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Chapter 14
Computational Thinking: Toward a Unifying Definition

Peter J. Rich and Matthew B. Langton

Abstract This chapter reviews the current state of Computational Thinking (CT)—an idea that promotes the use of computer science concepts to enhance problem solving in various subject domains. Although millions of dollars have been spent promoting CT, our review revealed that in spite of various studies on the application of CT and the pedagogical promise, few studies have sought to operationalize the term "Computational Thinking" for curriculum or assessment. We conducted a Delphi study to gain consensus among experts in CT to formalize a definition and clarify the latent educational possibilities. The results of the Delphi study are reviewed followed by a discussion for future directions of Computational Thinking research.

Keywords Computational thinking • Computer science • Problem solving

1 Introduction

For years, researchers in the computer science and education fields have sought to promote computer programming as a way of learning to problem solving (de Corte & Verschaffel, 1986; Pea & Kurland, 1984; Soloway, Lochhead, & Clement, 1982). Proponents for the acquisition of programming in general elementary and secondary education can be seen as far back as the 1960s. Such proponents have sought to highlight the extant educational advantages in teaching kids to program—specifically, as a means to promote problem solving as well as to enhance learning of algebraic concepts (Feurzeig, Papert, Bloom, Grant, & Solomon, 1970). More recently, Wright, Rich, and Leatham (2012) identified programming as the new literacy that all children will need to know in the twenty-first century.

In 1969, the National Science Foundation funded the LOGO Project. The project, conducted by Seymour Papert, was an attempt to develop "a new mathematics curriculum

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in which presentation depends *fundamentally* on the use of computers and programming" (Feurzeig et al., 1970, p. 13). In their report to the NSF, Papert and his colleagues specified the relevance of teaching programming languages in general, but specifically within mathematics. Specifically, as a means of "helping the student strive for self-consciousness and literacy about the *process of solving problems*" (p. 16). Despite these cited advantages, subsequent studies on the transfer of knowledge between computer programming and mathematics have demonstrated mixed results (Clements & Battista, 1990; Palumbo, 1990; Pea & Kurland, 1984).

In the last 10 years, however, there has been a resurgence in the push for computer science education and programming in K-12 education. Considering the repeated correlations noted between success in mathematics and computer programming (Rich, Leatham, & Wright, 2013), learning to program may have a significant impact on the way learners approach mathematics (Rich, Bly, & Keith, 2014). Recent years have shown a coalition of various organizations promoting computer programming both within and without education. Organizations such as the International Society for Technology in Education (ISTE), Code.org, the Computer Science Teachers Association (CSTA), and Google are currently promoting programming as an educational endeavor in STEM education as well as a digital age skill. There is an increasing movement worldwide to make computer science in some form part of the common schooling experience. Code.org has been successful in advocating that a computer science course may count toward a mathematics or science credit, which (as of this writing) is now the case in 30 states in the USA. In Japan, the teaching of robotics in elementary and secondary education is commonplace and widespread. The United Kingdom recently became the first large developed nation to require that computing be taught throughout all of a child's education, demonstrating political movement toward the teaching of computation. Code.org's efforts have probably been the most visible widespread effort to encourage young people to learn to code, with over 78 million having now tried their hand at an hour of code in just over 18 months (code.org, 20 Dec. 2014).

Within this context, Jeannette M. Wing of Carnegie Melon and Microsoft, in 2006, released her seminal presentation on the idea of computational thinking (CT)—promoting the skill of problem solving to various subject domains outside of computer science. According to Wing (2008),

> Computational thinking is taking an approach to solving problems, designing systems and understanding human behaviour that draws on concepts fundamental to computing. (p. 3717)

In addition, Wing (2011) has stated that computational thinking draws on mathematics as its foundation and cited instances of its usage in various disciplines such as biology, geosciences, economics, healthcare, journalism, and the humanities.

Thus, computational thinking serves as perhaps the most recently cited attempt to bridge the gap between computer programming and mathematics and other domains to facilitate problem solving. Following Wing's presentation, many organizations as well as several academic institutions have investigated the use of CT in an array of learning contexts among various age groups. As the world moves toward teaching students to think computationally, it is important to define what computational thinking means. Creating a taxonomy of computational thinking principles and concepts is a critical step toward defining what ought to be taught in upcoming computational thinking curricula. The next section of this chapter reviews several of these studies on "Computational Thinking" as well as the methodologies used.

1.1 Defining Computational Thinking

Several authors have attempted to define what they mean by computational thinking. Seymour Papert first discussed the notion when promoting that students learn to solve problems through Turtle Geometry. Peter Denning (2009), a prominent computer scientist, contended:

> Computational thinking has a long history within computer science. Known in the 1950s and 1960s as 'algorithmic thinking,' it means a mental orientation to formulating problems as conversions of some input to an output and looking for algorithms to perform the conversions. Today the term has been expanded to include thinking with many levels of abstractions, use of mathematics to develop algorithms, and examining how well a solution scales across different sizes of problems. (p. 28)

Jeannette Wing (2008) argued that computational thinking is not limited to computer programming. Rather, it involves conceptualizing problems in abstract ways that combines mathematics and engineering and is in fact utilized in all professions.

> Computational thinking is a kind of analytical thinking. It shares with mathematical thinking in the general ways in which we might approach solving a problem. It shares with engineering thinking in the general ways in which we might approach designing and evaluating a large, complex system that operates within the constraints of the real world. It shares with scientific thinking in the general ways in which we might approach understanding computability, intelligence, the mind and human behaviour … The essence of computational thinking is abstraction. (p. 3718)

Fundamentally, Wing and her group of researchers at the Center for Computational Thinking have summarized computational thinking into the ideas of algorithmic thinking and abstraction for the purpose of scale.

Representing the ISTE and the CSTA, Barr, Harrison, and Conery (2011) identified computational thinking as a problem-solving process that includes: (a) the formulation of problems that utilize technology to solve them, (b) the logical organization and analysis of data, (c) abstraction through data representation, models, and simulations, (d) automation of algorithms, (e) improving programs through efficiency measures, and (f) generalizing this problem-solving process to be used across problems and domains. The ISTE and the CSTA have used this operationalized definition of computational thinking to create materials that demonstrate how to integrate (or recognize) computational thinking across the curriculum from kindergarten to twelfth grade (see http://csta.acm.org/Curriculum/sub/CurrFiles/472.11CTTeacherResources_2ed-SP-vF.pdf).

Other organizations have provided similar definitions, though they may emphasize one point more or less. For example, Code.org boils computational thinking down to: (a) decomposition, (b) pattern recognition, (c) generalization and abstraction, and (d) algorithm design. Representing the MIT media lab, Brennan and Resnick (2012) use the Scratch programming environment to teach children to think computationally. They approach computational thinking as more than just a conceptual approach to problem solving. They use the constructs of concepts, practices, and perspectives to describe the many facets of learning to think computationally. Indeed, our own research (Rich et al., 2014) has demonstrated how learning to program may affect more than just our cognitive understanding, but our attitude toward problem solving and mathematics.

Despite the many similarities in how computational thinking has been operationalized, there remains a good deal of difference in what aspects of computational thinking different groups adhere to. Brennan and Resnick (2012) themselves recognized this difference stating, "there is little agreement on what a definition of computational thinking might encompass" (p. 2). In 2010, the National Research Council convened a meeting of minds to discuss the scope and nature of computational thinking. The report openly admits that there are wide-ranging opinions on the topic and that the purpose was not to create a consensus or recommendations. As such, the report served to generate more opinions rather than a clear set of principles to work from. Grover and Pea (2013) explored this fragmentation and asked perhaps some of the most relevant questions that serve to highlight why a consensus would be so important. They stated,

> The workshop, however, threw into sharp relief the lack of consensus that seems to have bedeviled this space. Some of the central questions left unanswered by the workshop included the following: How can CT be recognized? What is the best pedagogy for promoting CT among children? Can programming, computers, and CT be legitimately separated? (p. 40)

Grover and Pea then sought to explore the various definitions proposed of computational thinking, concluding that there are several elements that comprise computational thinking proposals and curricula. Namely abstractions and pattern generalizations; systematic information processing; symbol systems and representations; algorithms; flow, control, and decomposition; iterative, recursive, and parallel thinking; conditional logic, efficiency and program constraints; and debugging/identification of errors.

In an increasingly computational world, learning to think computationally is an important ability and disposition to develop. As such, it becomes increasingly important to know how to structure and create curricula that will successfully foster this type of problem solving. Yet, there remains dissention among what constitutes the scope and nature of computational thinking, even though some of the brightest minds have convened to discuss this very topic.

Because we are personally interested in fostering computational thinking, and in developing curricula and approaches that promote it, we set out to find consensus not only on the scope of computational thinking, but also on its structure. The purpose of this study has been to take a multiphase approach to define what the "experts" are calling computational thinking and to come to something of a consensus on how it might be structured.

2 Methods

We approached the problem of identifying a community consensus for an operational definition of computational thinking in two phases. In the first phase, we conducted a literary analysis of articles related to the study of Computational Thinking in K-12 education. From these, we identified each time when authors indicated they used computational thinking and the specific activity they described engaging in. In the second phase, we conducted a Delphi study. The purpose of a Delphi study is to "obtain the most reliable consensus of opinion of a group of experts" through surveys and questionnaires (Linstone & Turoff, 2002, p. 10). Delphi participants remain unknown to each other to ensure independent thinking and to avoid dominant opinions to influence the group. For our panel, we used the authors and other identified professionals from our literature review who engaged with computational thinking in our initial review as the experts. Our hope was that, through an initial review of disseminated literature, and a subsequent probing of expert opinion, we would be able to identify foundational concepts of computational thinking, and begin to tease out the structure of said concepts as they interrelate. We describe our methods and results from each of these phases in greater detail below.

Phase I. We specifically used the search term, "computational thinking" and limited our search to efforts since 2007, searching Google Scholar, ERIC, and JSTOR. Over 100 different articles were identified. These varied greatly in length and content, with many ACM-type articles being short summaries of presentations given at computing conferences, while research studies tended to reside in domains outside of computing venues (e.g., educational research).

From the identified studies, we found 81 descriptions of activities engaged in to teach or utilize computational thinking. We strove to identify a title, description, and example of each term, using the authors' own descriptions and examples where possible. For example, Repenning, Webb, and Ioannidou (2010) discussed pathfinding, describing it as an agent following a path that will lead to its desired destination. The example they provided was one of people finding food in the popular game The Sims®. We subsequently analyzed these 81 results to look for similarities in the description of terms. Some of these were readily obvious, such as "transport" and "transportation," defined as the act of one agent carrying another agent. Some terms described activities that fostered computational thinking, like programming robots. We deemed these as important activities, but recognized that while these may have been activities that lend themselves to promoting computational thinking, they did not constitute the basis of an operational definition for describing the constituent parts of computational thinking itself. As such, we eliminated these from our definition of computational thinking. As our purpose was to identify fundamental concepts and processes of computational thinking, we also chose to exclude some ideas that are clearly important computational constructs, but that may constitute advanced practices, utilized in specific and advanced specializations within the field, such as specific sorting algorithms. They could clearly be deemed computational, but it would be entirely possible for an expert in computational thinking to neither use nor know some of these more advanced topics. One such example of this occurred with specific sorting algorithms. We collapsed all the specific algorithms and approaches to sorting into the broader concept of sorting itself. In the end, we developed a refined list of 29 unique terms (see Table 14.1).

3 Findings: Phase II

The purpose of this study was to come to a better understanding of the computational thinking construct and to reach consensus in defining it in a level of detail heretofore not agreed upon. Our preliminary review in phase one yielded over 100 articles on the subject of CT with various methodologies and definitions. These articles helped us aggregate common themes in terminology as well as concepts or processes associated with CT. This laid the groundwork for the development of phase two of our research, a Delphi study to collect from the experts their definitions of computational thinking.

The intent of the Delphi study was to draw individuals from various backgrounds and experiences implementing or investigating CT. The study was distributed by email as a survey to over 100 individuals, whom we identified during our review process, from various backgrounds such as K-12, higher education, military, and industry. The survey was divided into two main areas. The first, demographics, included questions regarding occupation, education level, and background with computational thinking. The second, defining CT, included questions regarding classification of various concepts and processes previously associated with CT but never arranged in any systematic manner. Participants were also asked to provide any additional concepts not mentioned in the survey and to provide examples of these concepts in action.

The survey yielded a 22 % response rate, representing a broad range of experience and background knowledge with the construct. Based on the results, the majority of respondents hailed from institutions of higher education with 68 % attaining a doctoral degree and 37 % attaining up to at least a master's degree. This was useful as it provided us with an understanding of how CT experts are studying it and in what contexts—namely in formal research settings either within higher education or K-12. This was confirmed by the responses specifying context for teaching and implementing CT (see Table 14.2). "Teaching others to think computationally" referred to the practice of helping others to apply CT principles within a particular context. "Implementing computational thinking" referred to the implementation of CT principles through a formalized structure, curriculum, or other learning activities that elicited those principles from learners.

Interestingly, 44 % of experts indicated that they taught others to think computationally with K-6 graders, with 39 % implementing a CT curricula within this same age group. This is noteworthy given that the bulk of computational thinking research has emphasized a focus on 7–12 graders and above, whereas our findings indicate that many practitioners themselves indicate they are working with K-6 graders to teach computational thinking. This suggests that the focus of CT research may be more widespread in K-12 than that which is being disseminated through research findings.

Table 14.1 Computational Thinking Terms Presented to Respondents in Phase II

Term	Definition
Algorithm building	A functional representation of a problem such that a given input results in a predicted output
Arrays	A collection of elements, representing key/value pairs
Communication	Transmission of information from one process or object to another
Conditional Logic	An "if-then-else" logic structure, and often involves players describing the chain of events that might happen, based on the game rules, should a particular action be taken
Coordination	Control (through Communication, for example) of the timing of computation at participating processes in order to achieve a certain goal
Data collection	The process of gathering and organizing information
Data representation	Accurately presenting data in multiple visualizations without changing the nature of the data
Debugging	Diagnosing errors in logic or behavior. It often involves clarifying the execution and definition of rules or strategies
Design	The organization (using abstraction, modularization, aggregation, decomposition) of a system, process, object, etc.
Distributed processing	Different pieces of information or logic are contributed by different players over just a few seconds during the other processes of debugging, simulation, or algorithm building
Efficiency	Evaluating the effectiveness of performing a set of procedures to see if it can be done more quickly or with fewer resources or if there is a better algorithm to be used
Evaluation	Judging the relative benefits and constraints of specific subcomponents of a particular process
Event handling	Processing an action (e.g., keystroke, mouse click, touch)
Function	The encapsulation of a set of procedures. These may accept variables as input, run a process with these, and provide an output
Group problem solving	Solving a problem using multiple individuals
Hashing	A system of rules to classify pieces that could fit into more than one category
Iteration	The repetition of a mathematical or computational procedure applied to the result of a previous application
Measurement	How about analyzing and categorizing data in such a way that it can be compared in degree (often quantitatively)
Model/simulation construction	A method of using representation on a small scale or in a virtual environment to represent a larger experiment
Negotiation	Groups within the team working together to merge parts of the solution into the whole
Operators	An object that is capable of manipulating operands. These often represent mathematical operations
Organizing data	Separating information into similar categories by distinguishing features

(continued)

Table 14.1 (continued)

Term	Definition
Parallelization	Taking information or data and applying it to multiple experiments at the same time with the key variable or parameter altered for each experiment
Pipelining	A way of executing a method or process that is the most efficient in time and resources
Problem decomposition	Breaking problems down into smaller parts that may be more easily solved
Recollection	The encoding and organization of data into its parts or functions to make it efficient to search and perform other operations on those objects
Recursion	A process that repeats itself until a specific condition is met
Sorting	Organizing data by arranging that data according to a specified criterion
Variable	A container that stores a single piece of information

Table 14.2 Background with computational thinking

Context	*teaching* others to think computationally (%)	*implementing* computational thinking (%)
Higher Education	72	61
Grades 7–12	67	61
Grades K-6	44	39
Business/Industry	22	33
Government	11	11
Military	6	6
Other	11	22

As others have noted (Grover & Pea, 2013), consensus on the definition of CT has been disjointed and has led to further fragmentation of the idea, as well as the underlying forces at work. We asked participants to classify various ideas or concepts previously detailed in the literature as integral components of CT. Based on our preliminary literature review, we found that the majority of these forces could be categorized into two themes: concepts and processes. Here, we define "concepts" as foundational building blocks or ideas—the primary ideas upon which all computational practices, skills, and attributes are based. Secondly, we define "processes" as systematic ways of applying concepts to reach an intended outcome—the computational practices themselves, undertaken to solve problems or execute solutions. In an effort to map out the relationships between these underlying forces of CT, we asked participants to categorize them according to these themes.

In order to place a term into one category or the other, we determined that at least two-thirds of respondents must have identified that term as either a concept or a process, respectively. Respondents could place a term in a specific category or leave it out altogether. This means that not all terms were voted into either list. The resulting table therefore reports on the proportion of respondents that placed a term in each of

Table 14.3 Consensus on categories

Concepts	Proportions (%)	Processes	Proportions (%)
Conditional logic	75	Communication	75
Efficiency	83	Debugging	83
Hashing	67	Group Problem Solving	67
Iterators	83	Negotiation	75
Parallelization	75	Organizing Data	83
Pipelining	75	Problem Decomposition	75
Recursion	75		
Loops	75		
Variables	83		
Functions	75		
Arrays	75		
Operators	67		
Event handling	75		

the respective categories. Our findings showed that the majority of agreed-upon ideas were considered to be concepts, or foundational building blocks of CT (see Table 14.3). This does not indicate that there are more computational thinking concepts than processes, but rather that experts more often agreed upon the identification of an idea as a concept than they did with CT processes. We are encouraged by the implications of this agreement. It suggests that there may be clear agreement from at least two-thirds of experts on the concepts that make up computational thinking.

CT terms that did not have at least two-thirds agreement were algorithm building, coordination, data collection, design, distributed processing, evaluation, measurement, models and simulations, recollection, and sorting. It was curious to us that, of all these terms, only sorting was one that our research team had identified as a concept (our own groupings were not shared with respondents, so as not to bias their responses). Furthermore, had one more person put sorting into the "concepts" categorization, it would have met the criteria for two-thirds inclusion in our list. To us, this suggests that there is relatively widespread agreement among experts on what constitutes a computational thinking concept, at least among those that we were able to draw from the literature. While the concepts listed here are in no way a complete or comprehensive list of CT concepts, it might be argued that these concepts enjoyed such widespread agreement because they are the foundational concepts upon with much computational thinking is based. Further research is needed to warrant such a claim, but if such research validates this observation, then this list may provide potential guidance to those designing curricula and standards for computational thinking in early education.

In addition to these agreed-upon terms, we allowed respondents to add other terms that were not in our list. Respondents added several ideas (both concepts and processes) not included in our list, such as data analysis, data processing, data representation, open-ended problems, persistence, tolerance for ambiguity, and confidence. While many of the ideas listed indicated potential concepts or processes,

Table 14.4 Categorization of abstraction, automation, and analysis

Abstraction	Automation	Analysis
Design	Event handling	Efficiency
Functions	Hashing	Evaluation
	Iterations	Recollection
	Loops	
	Operators	
	Parallelization	
	Pipelining	
	Recursion	

others implied more dispositional aspects involved when thinking computationally. These findings correlate with the computational thinking categories in the research of Brennan and Resnick (2012) who defined a framework of "concepts, practices, and perspectives" to describe computational thinking. While the results do not definitively categorize these elements, they do suggest that CT may in fact include fundamental ideas, active processes, as well as dispositional or even attitudinal qualities at work.

In addition to mapping the relationship between these themes, we also sought to understand the underlying relationships of the agreed-upon concepts and processes to a specific organizing framework: abstraction, automation, and analysis. Our literature review in phase one of the study showed the repeated mention of these actions. Wing (2008) explicates the importance of abstraction as fundamental to thinking computationally. Here, we defined "abstraction" as taking a specific idea or situation and making it into a more general definition for use in testing. We defined "automation" as the repeated action of running created algorithms and processes in order to generate data for an intended outcome. Lastly, we defined "analysis" as examining mined data and gauging whether the results require further automation with different variables or parameters.

Thus, we sought to understand not only how experts chose to categorize the many underlying forces at work, but also to understand where a process (e.g., recursion) fit into the operational framework of abstraction, automation, or analysis. Experts were thus asked to categorize terms into one of the three processes (see Table 14.4). We again defined consensus as two-thirds agreement. The results indicated that most of the processes, according to experts, fell under automation.

While this may seem like clear agreement, we are not confident in the results of this last task. We describe our reticence to make any conclusive decisions regarding this framework in the following discussion.

4 Discussion

The results of our Delphi study revealed that there are a multiplicity of areas in which CT is being implemented and taught by researchers and practitioners, particularly in higher education and secondary education. Responses also showed that it is possible to establish at least two-thirds consensus on a variety of nuanced ideas related to CT. For example, many underlying ideas were categorized as "Concepts" (e.g., recursion, variables, pipelining, parallelization, hashing). However, due to issues of response rate and likely disagreement among participants of the classifications (i.e., concepts and processes) we provided, consensus was inconclusive in some areas. When respondents were provided with a forum for open-ended responses, it was clear that using Wing's (2006) categorizations as an organizing structure for CT is problematic, at least in the views of several experts. One person described this as a conflict of positioning a practice in two different places, by stating,

> I have a hard time using these terms to categorize abstraction; for example communication is used to talk about an abstraction and is also used to talk about the process of analysis, no?

Another respondent indicated that the use of these categories to organize CT "diminishes the utility and veracity of your survey." Respondents' reticence is well noted, though we find it curious that there is a clear similarity between these categories and those proposed by the groups who are most vocal about supporting and promoting computational thinking. Obviously, the Center for Computational Thinking at Carnegie Melon, led by Janette Wing herself, promotes this categorization. Code.org, another popular promoter of the need to learn computational thinking (primarily by teaching kids to code), organizes CT into the categories of Decomposition, Pattern Finding, Abstraction, and Algorithms, which closely mirrors Wing's framework. Finally, the ISTE and the CSTA of America have organized CT into six points, three of which involve analysis, abstractions, and algorithms (through automation). Thus, while there may appear to be consensus as to how to organize CT practices and concepts among those who are most vocal in promoting CT, our research demonstrates that this same consensus is not present among CT experts, many of whom were drawn from these very organizations.

Our purpose in pursuing this research has been, all along, to reveal any inherent structure to computational thinking concepts and processes, in order to inform curricular decisions regarding the teaching of computational thinking. This is especially important in earlier grades than computer science courses are currently taught. In 2014, the United Kingdom began requiring that all pupils learn to think computationally starting with their very first year of schooling. Similarly, Estonia, the birthplace of Skype, mandated in 2012 that children would all need to learn to code, starting in first grade. Finland, Estonia's neighbor (and the provider of their programming curricula), has since followed suit. Israel has shown how teaching students to code can lead to a successful economy, despite the distractions of political turmoil. By introducing a rigorous high school computer science curriculum in the early 2000s, Israel's tech hub has become the most profitable in the world (http://www.bloomberg.com/news/articles/2014-07-29/gaza-war-can-t-stop-israel-s-tech-deals). New Zealand, Germany, Australia, and Denmark are beginning to teach students to code at younger ages (http://www.economist.com/news/international/21601250-global-push-more-computer-science-classrooms-starting-bear-fruit). These countries are not attempting to force young children to learn low-level programming languages, but rather note that,

> the idea isn't to start churning out app developers of the future, but people who have smarter relationships with technology, computers and the Web. (http://www.forbes.com/sites/parmyolson/2012/09/06/why-estonia-has-started-teaching-its-first-graders-to-code/, ¶ 1)

The teaching of computational thinking practices ought to help achieve this goal. While some results were encouraging and seemingly straightforward, others appear to be more contentious, demonstrating that experts disagree on an organizing structure for understanding computational thinking. On the positive end, we can confidently declare several computational thinking concepts to share widespread support and recognition as the building blocks for computational thinking. This high level of agreement among experts may indicate that concepts such as loops, iterators, functions, arrays, variables, hashing, pipelining, parallelization, and others (see Table 14.3) should be immediately picked up and incorporated into the instructional endeavors to teach computational thinking, if they are not already. While countries or regional governments are increasingly requiring or offering courses that foster computational thinking, they are not all providing standards for the specific concepts that must be taught in order to foster CT. Table 14.3 may be a first step to providing such direction, guiding the development of curriculum that will foster and reinforce these concepts through multiple iterations (for a discussion on why multiple iterations and perspectives is important to fostering long-lasting computational thinking, see Rich et al., 2013). Likewise, the processes provided in this chart demonstrate concepts and practices that students would need to be familiar with to engage in productive computational thinking.

We also recognize that there is still a need to provide an overarching framework for organizing these concepts and processes. A limitation of this study was that we attempted to force such a framework (based in the provided literature) on CT experts. It was clear from our results, however, that many found this framework to be inadequate to describe computational thinking concepts and practices. We had hoped that revealing such a framework would provide a top-level view of CT that policy makers and curriculum designers could use to organize CT practices. Further work in this area will likely need to bring experts together to negotiate the different organizing frameworks and tease out their differences in how they interpret these activities. The risk of such an activity is that the most dominant voices may win out, leading to the adoption of an organizing structure that does not represent the thoughts of the majority of experts. Nonetheless, we feel this framework is an important, and missing, piece of the discussion around computational thinking as it becomes an adopted practice in formative education.

Finally, in addition to our expected findings, we feel it is important to highlight the unexpected. As discussed previously, respondents added several ideas not included in our list. It is worth noting again that several of these ideas were more attitudinal or dispositional in nature. Ideas such as "confidence," "persistence," and "tolerance for ambiguity" seem to imply emotional elements that, according to several respondents, hold equal weight when attempting to define computational thinking in addition to the fundamentally cognitive elements. These findings support the "Operational Definition of Computational Thinking for K-12 Education" promoted by the ISTE. According to the ISTE (2011), the necessary skills and concepts of CT are "enhanced by a number of dispositions or attitudes that are essential dimensions of CT. These dispositions or attitudes include: confidence in dealing with complexity … persistence in working with difficult problems … tolerance for ambiguity." These suggested elements of a CT definition support and add credence to the definition offered by the ISTE and others who have proposed similar constructs.

In elaborating on these dispositions, we wish to also acknowledge the potential impact that these components of CT could have on other problem-solving domains. For example, could the disposition to tolerate ambiguity, acquired through a computational thinking curriculum, enhance a student's willingness to work through a complex trigonometry problem? Or, could a student's confidence in dealing with complexity aid her or him while engaged in an engineering problem? As emphasis is placed on teaching foundational concepts related to computational thinking, we emphasize the equal importance of fostering computational dispositions. As Wilkins and Ma (2003) emphasized within mathematics, "A person's mathematical disposition related to her or his beliefs about and attitude toward mathematics may be as important as content knowledge for making informed decisions in terms of willingness to use this knowledge in everyday life" (p. 52). We believe that emphasizing such computational dispositions can likewise help learners engaged in various problem-solving domains.

In sum, this research has revealed a commonly agreed-upon set of foundational concepts and processes for computational thinking (see Table 14.3). These may serve as a guide to what students must understand as they are introduced to computing in early educational efforts. As yet, there is no agreed-upon framework for organizing these concepts and practices. Further efforts to establish such a framework ought to be endorsed by a majority of experts, which would then lead to a common set of principles for guiding CT educational endeavors. Finally, and perhaps most importantly, CT experts were vocal in promoting not only the conceptual and procedural benefits of computational thinking, but also in pointing out the effect that learning to think computationally may have on learners. Further research needs to examine these attitudes and validate the existence of such dispositions. If they truly are fostered by engaging in computational thinking, then we have shown educators one more way to help students approach problems in productive and persistent ways.

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Part IV
Changing Tools and Learning Environments

Chapter 15
Designing the Flipped Classroom in Higher Education

Cheolil Lim, Sunyoung Kim, and Jihyun Lee

Abstract Many reports exist of courses in which a flipped classroom model was implemented, putting a much greater emphasis on conducting various learning activities during class. The redesign of existing university lecture courses as flipped classrooms, however, is limited by reports that simply describe learning activities and their effects on individual courses. In this study, two different university courses were redesigned as flipped classrooms and evaluated based on observation, survey, and interview data collected. The comparative analysis of the different course implementations and learner responses of each case showed that the type and amount of learning activities in the redesigned classrooms varied by levels of the learners, the subject matter, the teaching approaches of the previous course, and the types of activities that instructors thought were significant but insufficient. Moreover, surveys and interviews with learners on positive and negative aspects of the online video lectures, learning activities, assignments, and the overall flipped classroom model revealed differences based on characteristics of learners and composition of learning activities. This study is significant in demonstrating that flipped classrooms can be designed and managed according to the diverse composition of different courses, and in providing guidance on how to design a flipped course based on its unique features.

Keywords Flipped classroom • Instructional design • Higher education • Case study

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1 Introduction

Lecture-centered instruction is one of the most commonly used teaching and learning methods in higher education since it can deliver a great amount of knowledge within a short period of time. This method also has been heavily criticized, however, for failing to nurture higher order thinking such as critical thinking, problem solving, and creativity. Moreover, it is ill-suited to developing learners' social skills that are facilitated through interaction between instructors and peers. Learner-centered teaching and learning models such as problem-based learning, situated learning, and goal-based scenarios represents an alternative to unilateral knowledge delivery (Lim, Kim, Lee, Kim, & Han, 2014). Recently, the flipped classroom approach has gained particular interest among education experts and practitioners.

The flipped classroom and its underlying assumptions can be found in the terms "the classroom flip" (Baker, 2000), "the inverted classroom" or "inverting the classroom" (Lage & Platt, 2000; Lage, Platt, & Treglia, 2000) that originated in the early 2000s. In the flipped classroom, learners study with an online video lectures prior to class, and then apply or extend their understanding through active engagement in problem-solving activities in class, either through discussions with peer learners or with the help of teaching assistants and instructors (Bates & Galloway, 2012). Bergmann and Sams (2012) defined flipped learning in simple terms as the type of learning in which activities traditionally conducted in classrooms are done at home and conversely, activities usually done at home are conducted in classrooms.

Redesigning courses into flipped classroom model is one of the worldwide trends in higher education. Research report on a Software Engineering course at Miami University (Gannod, Burge, & Helmick, 2008), a Physics course at the University of British Columbia (Deslauriers, Schellew, & Wieman, 2011), a Basic Information Engineering course at Bentley University (Frydenberg, 2013), a Genetics and General Biology course at University of Missouri (Stone, 2012), and a Calculus course at University of Michigan (Berrett, 2012). In South Korea, the Korea Advanced Institute of Science and Technology (KAIST) and the Ulsan National Institute of Science and Technology (UNIST) have been employing flipped classrooms since 2012. In the Spring 2012 semester, KAIST implemented three flipped classroom courses and in Fall 2012 the number grew to 10. Over the Spring 2013 and Fall 2013 semesters, a total of 62 courses were taught in flipped classrooms, and the number is expected to further increase (Lee, 2012). In addition, several universities in Korea have instituted flipped classrooms on an individual and trial basis, which shows growing interests in flipped learning in higher education practices (Kang, Kim, Ahn, & Kim, 2014; Kim, 2014; Kim, Jeon, & Choi, 2014; Kim & Kim, 2014; Lim et al., 2014; Shin, 2014).

Case studies of flipped classrooms in higher education settings have provided data on management formats, composition factors, and outcomes (Berrett, 2012; Deslauriers et al., 2011; Frydenberg, 2013; Gannod et al., 2008; Lee, 2012; Stone, 2012). In most cases, flipped classrooms have been employed in the fields of science and engineering and composed of online video lectures before class, quizzes, discussion, problem solving and feedback during class, and wrap-up and review after class. These classes are generally reported to have resulted in significant effects in terms of learners' achievement, satisfaction, and participation (Bates & Galloway, 2012; Frydenberg, 2013; Gannod et al., 2008; Johnson & Renner, 2012). Nevertheless, it can be difficult to effectively redesign an existing university lecture course as a flipped one based simply on descriptions of learning activities and their outcomes. Even when classes deal with the same learning content, their design and application need to be geared to the particular characteristics of the field of the subject, instructor, and learners, as well as the teaching method used previously for the class (Kang et al., 2014; Lim et al., 2014). Thus, what is needed may be specific implementation cases in different contexts including how flipped classroom model changes from the previous version of course to a flipped version. In this study, we first designed and implemented flipped classrooms in an engineering and a math course at the university level. Next, we used the results to examine different implementation strategies and learners' responses to flipped classroom by subjects matter, learners' level, instructor's characteristics, and the teaching and learning approach, which we hope to provide design implications to research and practices of flipped classroom.

2 Methods

The Calculus 2 course and Nonlinear Systems Theory course that were redesigned as flipped classrooms during the 2013 Fall semester at Seoul National University in South Korea had very different characteristics although those are similar in that both deal with math-related content and the relatively small class size (less than 20 learners) in each, as noted in Table 15.1.

For each course, one person with a doctoral degree in educational technology and one graduate student supported the instructional design and management, and closely consulted with the instructor and teaching assistants prior to course implementation.

During every class, observational data was collected via manned or unmanned videotaping, and every student was surveyed at the time of mid-term and final examinations. Instructors were interviewed on how the course was run before implementing flipped classroom, and how different the before and after implementing flipped classroom model were. The five scale Likert survey asked about positive and negative aspects of online video learning prior to class, learning activities during class, after-class assignments, and the overall flipped learning approach to the Calculus 2 and Nonlinear Systems Theory. At the end of the semester, five learners from each class were closely interviewed one-on-one. Each interview lasted 40–70 min, which were recorded and transcribed for comparative thematic analysis.

Table 15.1 Characteristics of courses with flipped classroom

		Calculus 2	Nonlinear Systems Theory
Overall course information	Category	Compulsory basic liberal arts course	Elective course within the major
	Level of difficulty	Mid-Low	High
	Prerequisite courses	Calculus 1	Linear systems theory
	Language	Korean	English
	Video materials	Prepare each week; 2–3 clips with 20 min. running time per week	Already prepared; 3–4 clips with 20 min. running time per week
Learner	Grade	Freshmen undergraduate	Master's and doctoral graduate level
	Number	18	12
	Department	Mathematics education	Electrical and Computer Engineering
	Prerequisite Completion	Completed by all learners	Completed by nine out of twelve learners
Instructor	Experience with running the course	Run for first time in a decade (in rotation by professors of the department)	Run for the last decade
	Previous teaching and learning method	Lecture + problem solving with team projects and discussions	Lecture focusing on concepts using PowerPoint slides
	Motivation for implementing flipped classroom	• Improving understanding of conceptual equations and formulas through various visual materials	• Enhancing understanding of subject matter using English online video lectures before class and Korean in class
		• Igniting learners' motivation by implementing additional and varied learning activities	• Identifying learner misunderstandings and correcting with problem solving
			• Generating questions from learners

3 Results

3.1 Composition of Classes Designed for Flipped Classroom

After implementing the two redesigned courses, course structure and learners' feedback showed different design implications. Since the two courses were originally different in terms of subject matter, learners, and instructors, they were redesigned and implemented as different types of flipped classrooms. The following Table 15.2 provides a comparison of the course learning activities in the before and after implementing flipped classrooms of the two courses.

Table 15.2 Comparison of learning activities before and after flipping two courses

			Calculus 2		Nonlinear Systems Theory	
			Before implementing flipped classroom	After implementing flipped classroom	Before implementing flipped classroom	After implementing flipped classroom
Before class (Online)	Video learning		–	○	△	△
	Question and Answer		–	–	–	△
During class (Offline)	Quiz (%)		–	15	–	–
	Lecture (%)		70	15	80	20
	Team discussion and presentation (%)		30	70	–	0
						40 % (after mid-term)
	Question and Answer (%)		△	△	△	20
	Instructor-led problem solving (%)		–	–	20	60
						20 (after mid-term)
After class (Online)	Assignment	Reflection journal	1 per class (approx. 10 times per semester)	1 per class (approx. 10 times per semester)	–	–
		Resource search & review	–	4 times per semester	–	–
		Reports	–	1 time per semester	–	–
	Question and Answer		–	–	–	△

Open triangle represents the activity implemented passively, and *Open circle* represents the activity implemented actively

What is similar in the two courses is the use of videos developed using video capturing software for online lectures. In both courses, the videos consisted of the instructor's voice and notes on learning materials. Figure 15.1 provides examples of screen captures of the video lectures for each of the two courses.

In the flipped Calculus 2 course, online video learning (not included in the before implementing flipped classroom) and quizzes were added to the previous version of the course. In addition, Resource Search & Review (RSR) and reports were added as a part of assignments while the proportion of problem-solving activities through learner-centered discussion and presentations increased. Compared with the before implementing flipped classroom, the flipped class contained a greater proportion of before- and after-class learning activities.

In the Nonlinear Systems Theory course, at the beginning of the semester voluntary Q&A was added before and after class. Prior to the mid-term exam, instructor-led problem solving was the major activity. After the mid-term, however, team discussions and presentations were added to encourage class interaction.

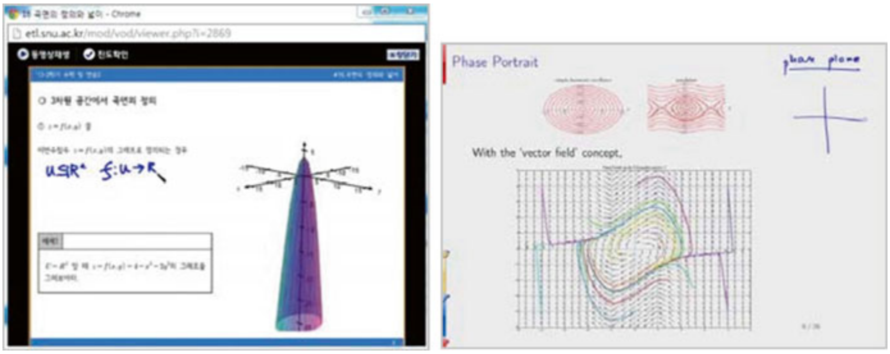

Fig. 15.1 Screen captures from video lectures for Calculus 2 (left) and the Nonlinear Systems Theory (right) flipped classrooms

3.2 Learner Feedback on the Flipped Classroom

The learner responses to the flipped classroom were derived from a survey that asked about positive and negative aspects of online video learning, prior to class, learning activities during class, after-class assignments, and the overall flipped learning approach to the Calculus 2 and Nonlinear Systems Theory courses.

3.2.1 Prior Online Video Learning

Learners in both courses were pleased that repetitive learning was more possible through online videos, since they could use them before class and after class for preparing for exams. On the other hand, learners felt burdened by a sense of obligation to engage in mandatory study separate from the official class. Some also responded negatively about the lack of efficiency of online video lectures compared to classroom lectures. A majority of learners were glad to be able to adjust the learning time and place at their convenience (Calculus 2), and some reported that it was challenging to learn through online video lectures delivered in English (Nonlinear Systems Theory). Table 15.3 summarizes learner feedback on the online video learning before class.

3.2.2 Learning Activities During Class

Learning activities for the Calculus 2 course included quizzes and cooperative learning activities. Table 15.4 summarizes learner feedback on the two learning activities during class.

Of the learners surveyed, a majority (eight learners) said the quizzes were not helpful for learning, though many (six learners) felt that quizzes should be naturally incorporated because they checked whether or not the learners had viewed the online

Table 15.3 Learner feedback on pre-class online video learning in flipped Calculus 2 and Nonlinear Systems Theory courses

Learner response (multiple responses possible)		Response frequency for Calculus 2	Response frequency for Nonlinear Systems Theory
Pros/Cons (±)	Responses		
+	It is helpful because I can repeatedly study the parts that I do not fully understand	7	9
–	It is burdensome as I am under an obligation to study in addition to the class	2	5
–	Online video lectures are less efficient than lectures delivered during class	2	3
+	It was good to be able to adjust learning time and place at my convenience	4	–
+	It was good since I could skip the parts that I know and selectively listen to the parts that I find it difficult	–	2
–	I hardly ended up listening to the video lecture as it was provided through online	1	–
–	It was regrettable to have less interaction that usually occurs in the classroom	1	–
–	Even though online lectures can be taken repeatedly, it was burdensome to take lectures delivered in English through online	–	1
–	Once one gets behinds the schedule, one helplessly falls behind the whole course	–	1

video lecture. This result may reflect the impression of learners that the quizzes were relatively challenging because they stimulated learning of new content and also burdensome because the quiz scores were reflected in their grade. Learners gave positive feedback about the collaborative learning activities, which they found helpful for problem solving because they were able to: engage in various kinds of thinking (five learners), enhance their understanding (four learners), and exchange ideas with each other (three learners). Other feedback included: "cooperative learning itself was very interesting," and "the more challenging the problem is, the more effective [problem solving] will prove to be."

Learners who enrolled in the Nonlinear Systems Theory course were required to view the online video lectures and raise questions either through the Learning Management System before class or directly to the instructor during class. The learning activities were mostly focused on questions and answers during class. In interviews, learners were asked for feedback on the kinds of answering methods they preferred during the Q&A time during class. Table 15.5 summarizes their responses.

As for in-class learning activities, in-class question and answer was most preferred (five learners) when one or several learners answered the questions while the instructor added relevant opinions and additional answers with a simple review of

Table 15.4 Learner feedback on in-class learning activities in flipped Calculus 2 course

Learning activities	Learner responses (multiple responses possible) Pros/Cons (±)	Responses	Response frequency for Calculus 2
Quizzes	–	It is not helpful	8
	+	It leads to learning to check whether the learner did video learning	6
	–	It is unreasonable that is reflected in the credits	1
	–	The quizzes are very difficult	1
Cooperative learning	+	It is helpful for solving problems with diverse kinds of thinking	5
	+	It is helpful for enhancing understanding of learning content	4
	+	It is interesting	3

Table 15.5 Learner feedback on in-class learning activities in flipped Nonlinear Systems Theory course

Learner responses	Response frequency for Nonlinear Systems Theory
Instructor-led Question and Answer with simple review	5
Instructor-led Question and Answer only	4
Instructor-led Question and Answer with problem-solving exercise and discussion	1
Learner-centered presentation	1
Instructor-led Question and Answer with brief preview of next class	1

the online video lecture. Slightly fewer (four learners) preferred instructor-led Q&A type. Overall, learners in the Nonlinear Systems Theory course were satisfied with the Q&A activities, and new activities were created to expand learner participation and the amount of time available at the end of class for brief class preview of the next class video.

3.2.3 Learner Feedback on After-Class Assignments

Reflection notes, RSR, and team reports were assignments given to learners in the Calculus 2 course. Table 15.6 contains a summary of learner feedback on the individual assignments of reflection notes and RSR.

Reflection notes were helpful for a majority of the class (six learners), specifically for reviewing learning content (five learners) and enhancing understanding (two learners). However, some (three learners) found daily reviews to be inefficient and artificial, and so, not at all helpful. Some learners pointed out that if reviews would be more productive if the questions genuinely encouraged reviews.

Table 15.6 Learner feedback on individual assignments in flipped Calculus 2 course

Learning activities	Learners' response (multiple responses)		Response frequency for Calculus 2
	Pros/Cons (±)	Responses	
Reflection Notes	+	It is helpful for summarizing learning content	6
	+	It can make me review learning content	5
	–	It is not helpful	3
	+	It is helpful for enhancing understanding	2
	–	It is not efficient	2
	+	Feedback is very helpful	1
	–	It is too formal	1
Resource Search & Review (RSR)	–	It is not helpful	7
	+	It increases interest in mathematics	4
	+	It is helpful for enhancing understanding	2
	+	It engages me in further study.	2
	+	It improves information searching ability	1
	+	It leads to practice time management	1
	–	It is unreasonable to have it reflected in grade	1

A majority (seven learners) felt that RSR, which required that learners search research theses or the Internet and share their findings with others, was not very helpful. This feedback, given by freshmen in an undergraduate course, may reflect a lack of research skills and associated feelings of reluctance and anxiety. However, some felt it helped them to increase their interest in mathematics (four learners), deepen understanding (two learners), and engage in further study (two learners). In addition, at least one learner mentioned each of the following in relation to RSR: improved information searching ability, improved time management practices, and unfair reflection in course grade.

Unlike Calculus 2, the Nonlinear Systems Theory course gave relatively few assignments and required learners to voluntarily upload questions and answers. Completing and submitting assignments was not counted for credit towards the grade. Accordingly, of the five learners who were interviewed, three mentioned the importance of assignments.

For this subject, it's good to have time for questions, (…) but it would be better and much more efficient if we had some problems to solve as assignments before class and have some time for discussion over the problems with the professor during the class (Interviewee 2).

As it is a challenging subject, it would have been better if professor gave us some problems as assignments before class; since we had to solve the problems during class, it was very challenging and even though having assignments itself maybe burdensome, it might be more efficient if we could think it over before class (Interviewee 3).

It would be more efficient if we had assignments. With no assignments, we don't do any problem solving on our own. Regardless of how difficult or easy the course is, assignments are necessary. In particular, easy questions should be handed out for difficult subjects and difficult questions for easy subjects. That is what assignments are all about. If too difficult questions are given for difficult subjects, it's not only impossible but also meaningless. Likewise, if too easy questions are given for easy subjects, it really doesn't help (Interviewee 5).

Based on feedback from learners, the instructor in collaboration with the designer concluded that Q&A during class could be more motivating and efficient if assignments and learning materials were provided prior to class along with the online video lecture. In particular, since Nonlinear Systems was a relatively difficult graduate course and less sensitive with regard to grade, learning materials and assignments could be suggested in the online video lecture prior to class so that learners had time to be better prepared for related Q&A.

3.2.4 Learner Feedback on the Flipped Classroom Overall

The feedback learners provided on the flipped classroom overall can be broadly divided into positive and negative aspects. In regard to positive aspects, learners of both courses gave the same opinions about the interaction and online video lecture in their respective courses. In terms of interaction, learners held positive views about the constant and active interaction between instructor and learners in the flipped classroom. Learners also positively evaluated the efficiency of learning from the online video lectures, in part because they made it possible to preview instruction before class, participate in the class more easily, and repeatedly study difficult portions of the materials.

Overall, learners who took the Calculus 2 course felt that their overall studying time increased and that they were able to acquire an efficient learning method as a result of the course. Learners who took the Linear Systems Theory course felt that they were able to prepare for in-class Q&A, engage in in-depth thinking as they reviewed their own questions, and prevent themselves from asking questions irrelevant to the class. Further, they felt better able to understand the lectures in the flipped classroom as compared to the traditional lecture class. Table 15.7 summarizes the feedback of learners about the benefits of the flipped classroom related to interaction, learning, and the video lectures.

Learners also shared their views about negative aspects of the flipped classroom. Learners in the Calculus 2 course focused on the size of the workload, content limitations, and asynchronicity of the online video lectures. As it was impossible to

Table 15.7 Learner feedback on benefits of flipped classroom

Category	Learners' opinions	
	Calculus 2	Nonlinear Systems Theory
Interaction	Constant exchanges between instructors and learners and active participation	
Video	• Repetitive learning is possible through online video lecture before offline class	
	• Efficient learning and participation	
Learning	• Increased individual learning time	• In-depth thinking over learning through Q&A
	• Acquisition of learning method	• Fruitful discussion and enhanced understanding

Table 15.8 Learner feedback on negative aspects of the flipped classroom

Category	Learners' opinions	
	Calculus 2	Nonlinear Systems Theory
Learning Burden	• Too many assignments (reflection notes, RSR, etc.)	–
	• Pressure to engage in participatory discussion	
	• Complying with class schedule	
Learning Content	Covering relatively small amount of content	–
Video	No interaction possible	Impossible to follow the class if online video lecture is not viewed
		Very boring

follow the class without viewing the online video lectures in advance and a great number of assignments were given, learners felt heavily burdened; they also complained that the range of subjects covered during the flipped class was much more limited than previous lecture-based course. Moreover, the lack of interaction during the online video class also was seen as a negative aspect of the course.

Conversely, for the learners in the Nonlinear Systems Theory course the negative feedback centered on the online video lectures. Learners found it very difficult to participate in and follow the class without having viewed the online video lecture in advance, as the class was led mostly through Q&A between instructors and learners. They also found the class to be very boring. Table 15.8 summarizes the negative aspects of the flipped classroom identified by the learners in both courses.

In addition, from the viewpoint of the instructors and researchers, some outcomes were surprising. In the Calculus 2 course, most learners stayed in the classroom after the class was over in order to continue discussions and learning activities. In the Nonlinear Systems Theory course, several learners asked for additional learning material for in-depth study even at the end of the entire course, and low-grade student showed satisfaction with the course because they experiencing individual support from teaching assistant, instructor, and mostly favorably peers. Moreover, the instructor in this course perceived the research skills of the graduate students to be greater than those of students in the comparable lecture-based course.

4 Conclusion

After implementing the flipped classroom approach to an undergraduate Calculus I course and graduate Linear Systems Theory course, we compared the flipped version and previous lecture version of the courses based on course information, learner feedback, and our observations of the instructors, learners, subjects, and teaching methods. The results indicated that the experience of the learners corresponded in some ways to the particular design of each flipped classroom. Further, the design and management of the flipped classroom was influenced by the instructors' experience and motivation for applying flipped classroom. Learner feedback on the flipped learning experience overall and relevant activities also differed depending on the course category, learners' purpose in learning, and sensitivity to course grade.

The following findings are significant for research and practices of flipped learning. First, the flipped classroom is effective for difficult subjects as well as easy ones. Most relevant studies concerned basic subjects such as Introductory Physics (Deslauriers et al., 2011), Basic Information Engineering (Frydenberg, 2013), General Biology (Stone, 2012), and Calculus (Berrett, 2012). In this study, the Calculus 2 was in this same category. The Nonlinear Systems Theory course, however, could be considered a course that is difficult even for graduate students, and the implementation of the flipped classroom design proved to be effective overall, a result derived from the strength of a flipped classroom in helping learners to repeat learning as needed through video lectures. In addition, the intensive in-class activities of the flipped classroom enable the model to help novice learners observe and learn superior peers' approaches. Finally, flipped graduate courses may enhance the research and learning skills of learners.

Second, it is necessary to pay attention to redesigned learning activities and assignments when applying a flipped learning model. In the Calculus 2 course, the learners tended to respond positively to familiar learning activities and assignments such as cooperative learning and reflection notes as opposed to new ones like quizzes and RSR. These reactions appeared to be stronger when the learning activities and assignments were associated with credit towards a grade. In contrast, in the Nonlinear Systems Theory course the learners wanted to do assignments that enabled them to check whether the learning was completed. They felt that the assignments should promote enhanced learning, and some learners actually made and completed their own assignments. Therefore, it is important for instructors in flipped classrooms to use assignments like reflection notes to frequently monitor the learners' thoughts and reactions to class assignments.

Third, instructional designers should advise professors who want to apply the flipped classroom method to consider their own tendencies and experiences teaching the course in question. The professor in the Calculus 2 course liked to experiment with a variety of learning activities and materials because she had majored in education and had taught Calculus 1 for the same learners in the previous semester. Therefore, instructional designers were able to propose the amount and rate of learning activities in which learners could be accommodated. On the other hand, the professor in the Nonlinear Systems Theory course tended to focus on the engineering content and stick to classical teaching methods. The instructional designers were able to show the professor the decreased level of interaction with learners when using classical methods such as individual problem solving and to recommend team-based learning activities to increase learner interaction. In addition, in flipped learning courses it is important to consider how to effectively use assistants as buffers and aids in the context of a professor's particular characteristics and relationship with learners.

Fourth, the instructor and instructional designers need to be sensitive to actions and thoughts of learners that are unrelated to study achievement and satisfaction. In this study, students' satisfaction was higher in both flipped courses, but differences from the exam scores of lecture-based courses were not statistically different. Unexpected phenomena did occur, however. Learners showed self-motivation in the Calculus 2 course by staying after class in order to debate ideas, and two students in the Nonlinear Systems Theory course sent an e-mail to the professor indicating a desire for further self-instruction after class. These phenomena show the potential for the flipped classrooms to produce even more unexpected positive outcomes than those seen so far.

The study was limited somewhat by consideration of only two courses, each with a small size of less than 20 learners. Another limitation was that the courses concerned only math and engineering. Future research should move beyond these limitations to study of larger classes in other fields of study, such as the humanities, social science, and so on. In this way, the present study may pave the way for advances in the design and guidelines for flipped classrooms.

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Chapter 16
DSIGN4CHANGE: 4Ps for Improving Management Education

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Abstract Despite the increasing attention given to educational technologies in business schools, the structure and objectives of management education have evolved little over the last several decades. Building upon the foundations of the long-standing critiques of business school education and the potential for student-centric learning, the authors propose that the use scenarios deployed in DSign4Change™ can significantly improve the learning experience. The authors discuss how this vision can positively impact management education by focusing on the 4Ps: Place, Platform, People, and Practice. In the conclusion to the article, the authors review the challenges and outcomes of their recent work in business and executive education in France and Great Britain.

Keywords Design thinking • Management education • Learning technologies • Pedagogy

1 Introduction

In the following pages, we argue that DSign4Change offers a fundamentally different approach to improving the quality of business school education. We begin our discussion with a quick review of current critiques of business education. We then explore the relevant tenets of design thinking to pinpoint the processes and the methods that can address these shortcomings. We conclude with an exposure of our own practice in business schools, ExecED, and corporate education.

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Mourshed et al. (2012) found that 74 % of European educational providers were confident that their graduates were prepared for work, but only 35 % of employers agreed. Various authors have well-documented the long-standing issues with management education in general and the MBA in particular (Dunne et al., 2006; Mintzberg, 2004; Pfeffer & Fong, 2002). These challenges hinge as much on the pedagogical choices that have been made as the reluctance of business schools to adapt their programs to new market challenges. To what extent can DSign4Change offer business schools an alternative vision for management education? Let's review a number of these issues to contextualize the value proposition of Design Thinking.

2 Pedagogical Challenges

One principal issue with business school education is its reliance on case study methodology that favors the notion of one best way. Culpin and Scott (2012) note that traditional case studies are most often sterile, impersonal, outdated, and subject to instructor bias. Case study methodology by its very nature favors normative prescriptions rather than depicting the complexity of real-life conditions in which companies succeed or fail. Most industries and markets today are not characterized by clearly defined problems and readymade solutions, but by challenges (declining profits, underemployment, engagement, etc.) in which understanding the nature of the problem is the major hurdle.

Another issue deals with the choice of business disciplines that focus on a limited number of analytical skills and competencies. The skills needed to address multitude of business challenges, ranging from hypercompetition to dealing with mass personalization, are often missing from traditional programs. Bennis and O'Toole (2005) claim that the focus of graduate business education has become increasingly shortsighted—and less and less relevant to practitioners.

A third objection addresses the inability of most programs to account for the uncertainty that characterizes most markets today. Snowden and Boone (2007) suggest both that most business problems requiring inductive or deductive reasoning have already been solved, and that the complexity of the problems that linger require different forms of decision-making. Whereas most business programs privilege inductive or deductive reasoning, neither is associated with the third level thinking associated with innovation.

A fourth criticism revolves around the project work given in class and out, which emphasizes an unrealistic view of teamwork. Roger Martin of the University of Toronto suggests that we teach a narrow form of collaboration involving finding someone with similar interests and then working together (Dunne et al., 2006). This approach has little in common with corporate practice where physical meetings are expensive, time-consuming, and often very difficult to arrange. In the modern workplace, managers are continually struggling with discontinuous time, competing on different agendas, and being evaluated on work accomplished outside the meeting room.

In a similar vein, the notion of productivity has changed. Sinofsky (2013) suggests that traditional visions of management based on hierarchy, top–down decision-making, and strategic planning are dubious mirages in markets flattened by the presence of ubiquitous information, connectivity, and mobility. In this view, productivity can best be studied today in gauging a manager's ability to act effectively upon real-time information.

Finally, teaching methods favor analytics rather than practice. Students who lack the experience to properly analyze and contextualize working knowledge poorly digest the codified, abstract premises that provide the staple of most management education programs. Mintzberg (2004) argues vigorously that teaching MBA students best practices won't help them learn how to manage. Organizations are complex phenomena. Managing them is a difficult, nuanced business, requiring all sorts of tacit understanding that can only be gained in context.

The introduction of learning technologies has done little to address these challenges. The progressive introduction of Learning Management Systems, MOOCs, and now mobile applications has filed to address the pedagogical challenges to management education. By simply mirroring existing courses and approaches, learning technologies have often amplified the challenges in providing more effective designs to learn about business.

E-learning pushes students out of the classroom, but it doesn't remove the need to take into account the context in which students learn. Context itself is a shell—learning not only occurs in a context, it creates context through the qualities of interactions between students and their professional environments (Sharples et al., 2007). In short, the pedagogical value of learning technologies isn't found in the applications themselves, but in how students, faculty, and organizations use these technologies to engage with their professional communities.

Attempts to improve digital technologies without accounting for the specific nature of higher education appear as ill-fated as efforts to improve the classroom by limiting or banning the use of mobile phones, tablets, and personal computers in class. The two are inherently intertwined in the modern classroom—we can't keep telephones out of the classroom not more than we should keep the classroom out of technology.

Many examples of learning technologies today try to mimic the conditions of either the classroom environment, or the workplace without taking into account the specific constraints that each environment imposes. The nature of both the work and learning places—the vision, the space, the participants, and the outcomes—go a long way to explaining the challenges of doing real work in the classroom, and effective continuous learning at work. The goal of technology might best be served by not reproducing either place but by providing a bridge between the two where real-life business challenges can be brought to school, and learning outcomes can be rapidly applied in the workplace.

To date learning technologies have simply relayed the inductive or deductive logics inherent in business education. Whether they integrated multiple choice exams or discussion around business cases, learning technologies have rarely helped elucidate the nature of wicked problems. As we have argued previously, one of the critical success factors for learning technologies are engaging the students, retaining their attention, motivating them to invest in the experience at hand, and encouraging the physical application or reproduction of targeted skills (Schlenker, 2014).

3 Design Thinking

Design thinking challenges the assumption of business as usual in order to create new connections (Brown, 2009; Melles, Howard, & Thompson-Whiteside, 2012). Design thinking encompasses the mental processes that are commonly used to design products and services. The associated process begins by analyzing behaviors and motivations, and then integrates the technical, financial, and commercial considerations that shape the life of a project. In management, design thinking is applied to project-based work that addresses complex or *wicked* problems (Anderson & Kolko, 2008; Dunne et al., 2006; Pasisi, Gibb, & Matthews, 2014).

The roots of Design Thinking can be traced back from classical concerns with participatory design that favor integrating use of studies into project prototyping (Di Russo, 2012). In his work on user-centered design, Norman (1998) stresses the need to take into account user's objectives and motivations in making things visible. In *The Sciences of the Artificial*, Simon (1996) suggests that design is a process that aims to improve the value of artifices like products, services, and systems.

The Design Thinking process can be juxtaposed with the tenets of traditional management. Martin (2004) suggests that the focus on classical management is in improving repetitive tasks, whereas the design approach models work on a project-to-project basis. The nature of work itself is most often classified within well-defined roles, where a design approach sees work inherently as a collaborative exercise. Management theories proposed problem-solving models that are either deductive (*top–down*) or inductive (*bottom–up*), while design theorists privilege *abductive* approaches (*inside–out*).

Managers evaluate an activity's importance by the size of its budget and its staff, whereas design thinking suggests that success is tied to unbundling wicked problems. Management practice uses constraints to define the scope of action, where, as designers see constraints as opportunities to redefine the scope of potential activity. Finally, and importantly, management education encourages students to focus on one best solution to a problem, whereas design theory seeks to encourage the development of the larger number of potential solutions to a problem.

Simon originally associated seven activities with the design process: Define Research, Ideate, Prototype, Choose, Implement, and Learn. Although there has been a debate since around which activities are critical to this process, practitioners generally agree that Design Thinking requires defining the right problem to solve, creating, and evaluating the different options, nurturing an environment conducive to experimentation and building, testing the proposed solutions in the real-world environment.

These same practitioners insist that these activities aim to develop specific skillsets in students and managers alike: the abilities to deal with ambiguity, to be curious, to develop holistic views of the problem, to develop empathy, to work collaboratively, and to maintain critical distance. As Waloszek (2012) concludes that design thinking can be understood as a methodology that combines understanding the context of the problem, creativity in generating insights and solutions, and rationality and feedback to select and analyze appropriate solutions.

A number of business schools have introduced design thinking over the last two decades as a subject of study. The value proposition of design thinking isn't however in analyzing its impact on business but applying the concepts of this methodology in developing management education as a whole. Specific points in which design thinking can improve how students learn about business include:

The student is inherently part of the problem that must be addressed. Teaching the student is less important in business education than helping future managers effectively address customer challenges. Each student brings unique motivations, experiences, and skillsets to class. Most cannot relate with the business context under study; their empathy and implication are prerequisites in solving the problems at hand. Finally, success depends upon practice: students must practice what teachers preach.

Business problem solving requires a much deeper understanding of the user and of the user experience than we normally teach in business schools. One of the core ideas in this vision is that the people using the products and services are different from those who manufacture and implement them. User experience is about creating memorable experiences that have a meaning for the consumer. Design thinking implies using quantitative and qualitative approaches to develop a better understanding of the data.

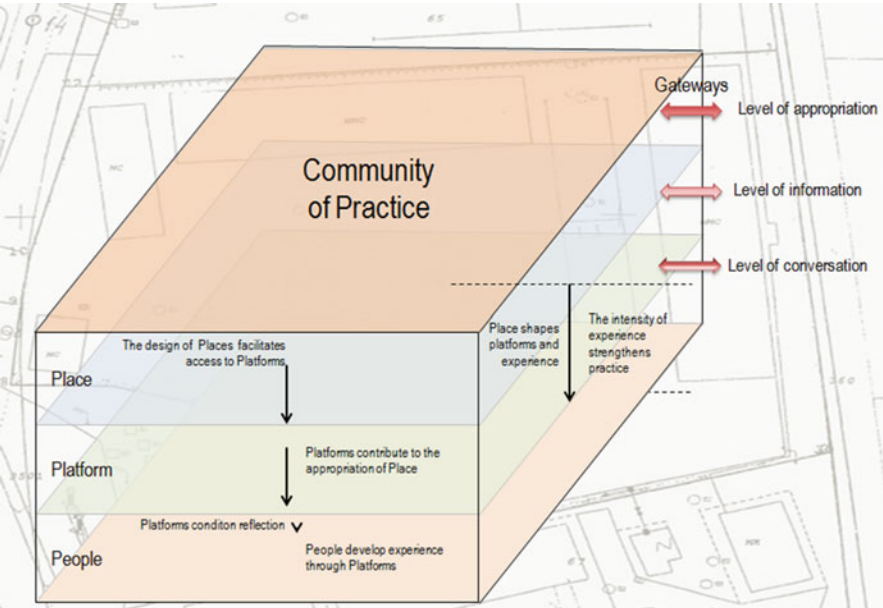
Business challenges are a result of a system of structures, patterns, and events, rather than just the events alone. Any system is a web of interrelationships between people, information, and physical technologies. There is a need to understand the essential relationships operating at various levels of the system, as well as different strengths and probabilities for change.

Design thinking takes into account how context shapes both the problem and the potential for viable solutions. In design thinking, a problem is not only defined by its operating context but also by the constraints imposed on the problem solver. The greater the constraints: the better the chances of producing truly innovative solutions. This approach postulates that constraints are a source of new ideas, and should be fully recognized as levers rather than inhibitors to creativity. The more constraints a problem solver is forced to confront, the better the opportunity to break out of the box of previous experience to find innovative solutions to the problem.

The logic inherent in design thinking can help students visualize solutions to complex problems that elude best practices. This abductive logic can be understood as the process of forming an explanatory hypothesis. Charles Sanders Peirce studies of the origins of new ideas led him to believe that innovation is tied neither to inductive nor deductive reasoning, but to logical leaps of the mind when our observations don't quit the existing frames and models. This form of modal reasoning called abductive logic explores what could potentially be true (Martin, 2009).

Design thinking insists on the necessity of formulating a large set of potentially useful ideas, services, and products, gradually improving their fit with the problems under study, prototyping, giving the product to the consumer and then improving it some more. The advantages of a prototype product, or simulating a service, include producing a better result at a more reasonable cost and contributing to strengthening empathy and engagement with the organization.

4 Place, Platform, People, and Practice



4.1 The 4Ps of DSign4Change

Based on our own pedagogical experience in Europe and abroad, we believe that the effectiveness of design thinking can be enhanced by focusing on the four foundations of *DSign4Change*. Critical considerations include:

4.1.1 Constructing a Holistic Approach That Focuses on Place

Management education is defined less by the presence of walls or computers than the nature of the experience that is nurtured in a learning place. DSign4Change borrows from the foundations of social geography in encouraging the construction of learning places around a clear vision, planned events, desired outcomes, identifiable actors, and bridges with the real-world. The vision corresponds to specific learning objectives, the events, and the outcomes to the activities designed to reach these objectives, identifiable actors to the coherence of the motivations and experience of the participants, and the bridges to the pertinence of the experience between learning places and professional and leisure time activities.

DSign4Change, rather than ignoring the limits of the classroom and the students' experience, recognizes that business challenges and solutions are context-dependent. The participants themselves will benefit from exploring the relationship between the content provided in each program and the context(s) in which it is distributed, analyzed, and discussed. As Sharples, Taylor, and Vavoula (2007) suggests, context itself is a shell—learning not only occurs in a context, it creates context through the qualities of interactions between students and their professional environments.

With this in mind, instructors, like practitioners, need to elucidate the context not only in the "classroom" but also in the management practice under study. How does the amphitheater, seminar room, or internet café contribute or hinder the learning experience? What are the differences between a company visit, a guest speaker's testimony, or the setting of a serious game and the actual practice of management? As in real-life, these considerations include geography, time, physical resources, and budget. Rather than minimizing these differences, DSign4Change suggests that the differences be used as part of the learning experience.

4.1.2 Developing Platforms That Elucidate the Ubiquitous Nature of Information

Class content is formal and informal, structured and unstructured. Reading lists in class are similar to project briefs at work: both are necessary but often incomplete in understanding what needs to be known to tackle the business problems at hand. If MOOCs (Massive open online courses) are more and more popular with school administrations, they often reduce learning to watching canned videos and chatting online. DSign4Change proposes a different direction: students are stimulated to explore actively what information is available, on the Web and off, from primary sources within business community to academic research and discussions.

Information platforms, as opposed to websites, are designed to accentuate the proximity between producers and consumers of data, information, and conversations. How does the physical layout of the auditorium, workshop, or seminar room facilitate or hinder the students' understanding of the context of the subject under study? What high- and low-tech tools are provided to encourage the student's implication and appropriation of the subject at hand? How does the course support documents mirror or differ from the information available in the real-world? How do the school and the instructor build bridges between the classroom and the workplace to encourage the participants to apply the lessons learned?

4.1.3 Developing Each Student's State of Mind (People)

What does it mean for a student to work at school? The responses from our own students at the beginning of each year varies greatly, for some it's doing the class readings, for others it's participating in class, and for the vast majority its handling the class assignments. DSign4Change suggests that the ultimate goal of management education is not spreading the good word but helping the students transform data and information into managerial action. Our vision implies that the learning outcomes depend upon helping each student manager understand how they use information to develop their managerial capabilities.

Work in management studies involves identifying the right problems to solve, creating and evaluating the different potential solutions, building an environment conducive to experimentation, and testing the proposed solutions in the real-world environment. How are the students framing the problems to be solved? How are they encouraged to analyze the visible constraints to fuel new ideas and potentially new products, services, or systems? How does the specific pedagogy, and the program as a whole, represent a call to action?

4.1.4 Co-Designing Learning Environments That Fosters the Development of Practice

Practices are methods and/or techniques that consistently provide pertinent responses to market demands. DSign4Change suggests that developing business practices, much like developing better managers, are part of both the challenge and the solution for management education. As Sinofsky (2013) would suggest, productivity in a business school cannot be measured in its product or service offer, but in the capacity of its faculty and students to provide pertinent responses to external demands. We take good note, and fully assume the potential contradiction of our vision with certain accreditation processes.

The potential of the practices is limited only by what the school is willing to accept and/or finance. Among the dozens of current student proposals are welcome halls as physical hubs in student-centric institutions that display incoming students' motivations, aspirations, and interrogations, sharing rooms like those of the chameleons that change atmosphere, equipment, and discussions in response to the subjects proposed by the student body throughout the year, and "living student newspapers" produced physically and virtually by the students based on class assignments and activities.

5 Case Studies

5.1 Design Your School

We have been applying the principles of DSign4Change to in the MBA France–India program in encouraging students to improve significantly the impact of the learning "place." One of the major aims of this MBA, which draws students principally from southwest France and the Karnataka region, is to provide accessible managerial skills to work cross-culturally. The objectives of the management innovation module were to introduce the students to the various forms of innovation, to elucidate varying practices in fields ranging from social commerce, omnichannel distribution to digital transformation, and to encourage the students to apply the lessons taught in small group projects.

A number of constraints shaped the project. To begin with, the diverse backgrounds of the students: engineering, technology, as well as the social sciences and the humanities, pleaded in favor of an integrated multidisciplinary approach to innovation. Second, the program's spatial distribution—one-third of the MBA is run in Pau, one-third in the Bangalore region, and one-third in internships in international companies—hinders the students' identification with a host school. Over the years, the need to build a stronger group identity and the deeper implication of the participants in the program have been constantly underlined by the program's staff. Finally, the majority of the students are constantly seeking to get out of class to practice management.

We incorporated the concepts of DSign4Change into a semester project called *Design your School*. In this crowd sourcing project, students were encouraged to use and apply the concepts of management innovation in redesigning learning places outside the traditional classroom, notably in the both the Commons and the Resource Library. The students were challenged to shape their *learning place* using physical resources, information technology, and change management. The students were invited to anchor their vision in the current students' interests and motivations, and then to redesign a space around a specific vision, use scenarios, events, and desired outcomes.

The preliminary outcomes of the project include several dozen student proposals from class participants, as well as a number of professors and students from others schools, on visions ranging from Feng Shui working environments to finance and distribution test labs to an innovation factories. Student participation proved markedly better than in many modules of the program; many students continued to pitch and improve their projects throughout the year. The module materials, as well as the students' projects have been incorporated into an interactive e-book that the students can comment and structure for their personal needs.

5.2 A Multidisciplinary Foundation for Management Study

We have developed the principles of DSign4Change in proposing a new approach to learning about management at France Business School (FBS). The merger of four business schools in 2012 gave birth to both FBS and a vision of management education based on a cross-functional management program. Behind this vision, the school has sought to appeal to a wide range of students by promoting innovation and entrepreneurship. The key to the program is a first semester agenda based on sharing and knowledge transfer among the different disciplines.

There have been several challenges in creating the conditions for pedagogical innovation. To begin with, the pedagogy needed to be restructured to solicit novel ideas, embrace challenges, and produce meaningful solutions for business. Course work had to be integrated in pedagogical processes that promoted collaborative work and prototyping. The traditional classrooms have given way to hotspots integrating co-working spaces and digital learning technologies (MOOCs, an LMS and broadband internet access). The instructors have been encouraged to become knowledge brokers opening gateways to real-life experiences.

Today, first year students are challenged to find fresh out-of-the-box solutions to today's major business problems. The wicked problems' they face are designed to strengthen their mental agility and develop their cognitive abilities for abductive reasoning. In class and out, students can write on the walls, build their own collaborative workspaces, and practice thinking-by-doing techniques (visual thinking, mocking-up, sketching, etc.). The student experience is based on an environment where problem-solving, prototyping, and testing products, services and ideas have become the staple of the pedagogical process.

Student evaluations indicate that DSign4Change develops twofold awareness: self-awareness on their capabilities to act as designers in producing ideas and solutions, and awareness on the power of collaborative work. The new program has accompanied a number of students in the creation of start-ups to put their ideas into practice both inside than outside the business school. Current students and the new alumni appear to create a cohesive community based on discovery and collaboration in line with the school's strategic vision.

5.3 An Interactive Onboarding Guide

In designing an international technology company's Interactive Onboarding Guide, we are working with the corporation to help its Operations Account Managers structure and react to real-time flows of data, information, and content. The company employs over 300 managers to handle the logistics of service and delivery in four regional operation centers on four continents. The corporation's strategic shift from selling software licenses to promoting software and devices focuses particular light on operations management as the employees must quickly absorb new knowledge and deploy new skills.

This shift in strategy has brought about a number of challenges in training new hires for the future challenges of software plus devices. The "one best way" to manage the new division does not exist as the corporation is exploring new markets. The operations managers are constantly on the go with little time to spend on classical classroom instruction. Communication between the different regional operations centers and between the logistics specialists themselves has been notoriously poor over the years. Finally, given the history of the company's success with desktop applications, the division has little experience with either mobile applications or mobile training.

The Interactive Onboarding Guide was conceived as an exercise in DSign4Change to address each of these issues. The texts themselves are delivered in the form of an interactive, social book that is updated each time the operations manager consults his tablet or mobile phone. Each page, each idea, and each theme can be alike, annotated, and shared by each manager, who can also consult the comments of his or her colleagues in real-time. The content is available off-line, permitting each manager to consult the book anytime and anywhere. Natural language search allows the reader to quickly locate key ideas from anywhere in the text.

The Onboarding Guide is currently being beta-tested worldwide. The Guide represents one of the corporation's first attempts to design and implement an application designed for a mobile workforce. The ability to take notes and share ideas inside the book offers employees a real-time tool to improve horizontal communication between the Operations Centers. The ability to update the texts in quasi-real-time offers the division the possibility to update its vision as the market challenges of software and devices evolve. Although it is too early to have any quantitative analysis of use of the application, preliminary feedback from the beta test team has been markedly positive.

In conclusion, we have put forward a proposal to take a fundamentally different approach to business school education. Our argument has been built upon a foundation of common critiques of the MBA: the bias of case study methodology, the mismatch between management theory and the practice, the lack of attention given to how most markets and industries are evolving. Our proposal is built upon the precepts of Design Thinking—understanding that the students are both part of the challenge and an integral part of the solution, focusing on abductive methods for solving market challenges, and dealing with both ambiguity and complexity.

Our vision goes beyond design thinking in suggesting that the value proposition for business schools is not in teaching the methodology, but in applying the approach to remodel management education. The scope of this effort should not be limited to improving cognitive approaches, but concreting to designing learning places, flows of information, and mindsets that support how students learn about management. Places, information, and mindsets are interdependent considerations in pedagogy that inherently influence the quality of education.

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Chapter 17
Informal Learning for Possible Science Selves

Leila A. Mills

Abstract A study of possible science selves as measured by a new instrument, Possible Science Selves (PSS) (*Cultural Studies of Science Education, 7*(4), 963–978, 2012), among high-school students is presented. Possible science selves are examined by gender, career interest, and desire to be a scientist, pre/post a unique science field-trip experience. Forty-four of $n = 88$ high-school participants from a small, rural public school parish in Louisiana, USA reported interest in seeking a STEM-related (science, technology, engineering, or mathematics) career. The PSS was used to examine changes in the *desired, academic*, *feared, and participation* factors for scientific selves in relation to participation in informal learning of science.

Keywords Informal learning • Possible science selves • Scientific identity • STEM learning

1 Introduction

There is a great deal of interest in *who* wants to be a scientist, *why* women do not enter some science-related career fields as often as men, and *if* we will have enough science-related professionals to meet future demand. The Government Accountability Office (GAO) of the United States reported in 2010 that approximately three billion federal dollars were spent on science, technology, engineering, and mathematics (STEM) education programs (Government Accountability Office, 2012). However, researchers have yet to reach a consensus on interventions that can be relied upon to increase students' participation in STEM professions (Nixon, Meikle, & Borman, 2013).

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This chapter presents research related to aspects of self-identity that relate to STEM career interest among students. Science selves serve as a gauge for examining the relationship of self concept with academic and strategic actions that promote success in attaining goals. The importance of informal learning for the creation and maintenance of students' science selves is highlighted because the informal-to-formal learning of science is thought to be key to encouraging participation in science-related careers (Osborne & Dillon, 2007). Informal learning of science can also contribute to students' liking of, and participation in, science activities that may assist in the development and maintenance of students' science selves.

Findings on PSS reported here are from one of several studies on the informal-to-formal learning of science and possible selves being conducted at the Laser Interferometer Gravitational Wave Observatory (LIGO) Science Education Center (SEC) in Livingston, LA. This research was funded by NSF grants, awards PHY0917587 and PH-0757058, to the Baton Rouge (Louisiana, USA) Area Foundation and the LIGO Cooperative Agreement with Caltech. The LIGO SEC is situated in a rural area near the community of students in this study. The LIGO SEC is known for field trips, family science events, community outreach programs, and university work-study opportunities.

The high-school student participants in this study had the opportunity to participate in a unique field-trip experience. The multipart LIGO field trip allows students to see the daily operations of a state-of-the-art science observatory and to meet scientists, science educators, and university student tour guides. Half-day field trips begin with a short video in the LIGO auditorium that introduces the science of LIGO and gravitational wave theory. Following the video, there is a pre-tour discussion on the science of LIGO; then, a tour of the science observatory and control room where operators use the latest technologies to monitor the onsite gravitational wave tunnels with interferometer for the detection of gravitational waves. Back at the SEC, science educators lead students in learning activities for the exploration of physical science concepts with simple, inexpensive materials. Finally, students explore the 50+ hands-on exhibits housed in LIGO's extensive interactive science education center. This study examines students' science selves after completing the LIGO informal science learning experience. A pretest/post-test design was used to identify significant changes on the PSS survey scales (Beier, Miller, & Wang, 2012). The premise is that the PSS may assist in advancing the understanding of the link between students' possible selves and performance (Cross & Markus, 1994) of goal-related, strategic actions—such as participation in science-related activities—towards the goal of attaining a STEM-related career.

2 Conceptual Rationale

2.1 Informal Learning of Science

Student attitudes toward science, thought to be generally positive in the initial school years, reportedly decline throughout a student's school career (George, 2000; Osborne, Simon, & Collins, 2003; Pell & Jarvis, 2001). Osborne et al. (2003) analyzed decades of literature on student attitudes toward science and reported a survey of the literature reveals numerous studies, all report a decline in students' science attitudes, with the decline beginning to appear at around age 11. However, research also indicates that students maintain different, often conflicting, attitudes towards real-world science and school science (Ebenezer & Zoller, 1993; Osborne et al., 2003).

Informal learning of science can encourage positive attitudes towards science and participation in science-related learning (Osborne & Dillon, 2007). As stated before, student attitudes toward school science reportedly decline across the school years (George, 2000; Osborne et al., 2003; Pell & Jarvis, 2001). However, students discern between school and real-world science, and they may continue to have favorable perceptions of real-world science, even as attitudes toward school science decline.

A National Research Council report (Feder, Shouse, Lewenstein, & Bell, 2009) identified six strands for the learning of science in informal environments. The first four strands presented by the NRC incorporate students experiencing excitement, understanding and generating concepts, as well as manipulating objects and asking questions, and reflecting on science as a way of knowing. The two remaining NRC strands state that participating in scientific activities and developing an identity as a person of science are indicative of informal science learning. These strands are closely related to aspects of science selves studied by Beier et al. (2012). This research seeks to advance understanding of facets of identity as a person of science in the metaphor of PSS and to examine relationships between possible selves and participation in science.

2.2 Possible Selves

Research on equity and participation in science education has indicated a need for a deeper understanding of science-related identity (Brotman & Moore, 2008). Self-image has long been recognized as a component of psychological development. Possible selves provide a framework for understanding important aspects of student self-concept, including those related to education/scholarship and academic choices/behaviors. Possible selves—self-images of current identity and future personas (Erikson, 1950)—can provide a measure of self-concept in academic areas such as career interest.

Possible selves are examples of mental components of adolescent development that support the solidification of person and formation of occupational identity (Super, 1980). Within Markus and Nurius' possible selves theory (1986), career interest can be viewed as an expression of self-perceptions and self-conceptualized selves. Based on psychological theories advanced by William James during the years 1890–1950, possible selves can be viewed as the images of self that are desired, hoped for, or feared (Oyserman & Fryberg, 2006). These images of self are thought to work together to motivate behavior (Shepard & Marshall, 1999).

Possible selves theory, as mentioned before, includes distinct aspects for *desired*, *expected*, and *feared* images of self (Oyserman & Fryberg, 2006). For example, if we examine Oyserman and Fryberg's (2006) dimensions of self for young girls, we might find that many *desire* to work with animals, they *expect* or *hope* to become a veterinarian, and perhaps, they *fear* obstacles that may prevent them from attaining this desired goal. Possible science selves as future projections of self (Packard & Nguyen, 2003) and scientific identity may prove to assist in understanding science-related career interests, fears, and most importantly, strategic actions towards attainment of career goals.

With the wide range of Oyserman and Fryberg's (2006) dimensions for possible selves (desire, expectation/hope, and fear), how do these work within one individual student? Balance is important. Two types of balance have been mentioned in possible selves theory. Possible selves are thought to guide behavior over time when they are balanced in terms of desire and strategies for a goal (Oyserman, Bybee, Terry, & Hart-Johnson, 2004). Additionally, possible selves have been analyzed for balance between desire and fear (Oyserman & Fryberg, 2006). Desiring a goal while having fear of failing to attain that goal would indicate having both a desired, self-identified goal and an awareness of negative personal implications of not attaining the desired goal (Oyserman & Fryberg, 2006). The balance of desired and feared possible selves in a domain is thought to support self-regulation and promote the development of strategic action towards attainment of the goal. The concept of possible selves has recently been expanded to possible science selves, which are discussed in the following section.

2.3 Possible Science Selves

Pajares (1996) stated that possible academic selves can provide a broad view of personal efficacy that may guide without imparting the most refined understanding of the complexities of motivation and behavior. Academic self-concept is a useful theoretical framework for understanding motivation, self-regulation, and school achievement (Marsh, 1990). Academic possible selves are thought to interact in motivating behaviors related to goals, self-regulation, and academic achievement (Oyserman, Bybee, & Terry, 2006; Oyserman, Gant, & Ager, 1995).

Science selves can be viewed as an aspect of academic selves. Packard and Nguyen (2003) applied the lens of possible selves to examine persistence in the science careers of women ($n=41$) who were 18–21 years of age. The researchers examined career plans at the end of high school and during the first and second years of college and also studied changing career trajectories. Participants reported that career-related work opportunities and intensive academic programs were important to the development of possible selves for career.

Most recently, possible *science* selves have been explored in relation to experience in technology-mediated environments, such as virtual reality, simulations, and video games. Foster (2008) suggested that video gaming may be effective in creating meaningful learning experiences. Lee and Hoadley (2007) indicated that massively multiplayer online games (MMOGs) can serve as valuable learning explorations that reinforce identity formation. Augmented reality and avatar identities are being associated with positive exploration among children who can gain experience in virtual worlds with an idealized self. Dodge et al. (2008) examined video gaming as a bridge to cognitive and communicative experience for personal growth and transformation. Beier et al. (2012) examined how science experience for development of possible science selves (PSS) can be acquired through gameplay with a serious science video game. There is a great deal of interest in the extent to which possible science selves can be used to understand goal attainment and competent performance (Cross & Markus, 1994). The following section discusses the role of action-oriented selves in attaining desired goals.

2.4 Strategic Action Possible Selves

Kuhl (1984) examined the relationship between goals and action. He stated that action-oriented participants were more likely to focus on success, approach a task with efficiency, and provide themselves with incentives for desirable actions. Smith (2006, p. 60) described possible selves as "the driving force within self-concept" and theorized that possible selves should play a systemic role in daily self-regulation of self-concept. The *participation* (in science) scale presented for this study from the PSS instrument (Beier et al., 2012) serves to gauge plans to take part in science courses and activities. The participation scale, viewed as a possible self, may link desire to action for a goal. Cross and Markus (1994) hypothesized that competence requires both a self-schema and ability in a domain. Action-oriented possible selves are associated with action towards attaining goals that can develop ability and competence in a domain.

3 Participants

The study presented here began in September 2014 when possible selves data were collected from high-school students ($n = 88$) from a predominantly African American, rural school district in Louisiana, USA. Participants were 58 % male and 37 % female, attending high-school grades 9–12. See Tables 17.1, 17.2, and 17.3.

Table 17.1 Descriptive statistics: frequency by gender

Gender	Frequency	Percent
Male	51	58
Female	37	42
Total	88	100.0

Table 17.2 Descriptive statistics: frequency by grade

Grade	Frequency	Percent
9	45	51.1
10	2	2.3
11	25	28.4
12	16	18.2
Total	88	100.0

Table 17.3 Descriptive statistics: frequency by career interest group

Career goal	Frequency	Percent
Non-STEM	43	48.9
STEM not Engineer	28	31.8
Engineer	16	18.2
Total	87	98.9
Missing	1	1.1
Total	88	100.0

4 Data Collection

Beier et al. (2012) developed and recommended the Possible Science Selves instrument as part of a study that examined the reliability and validity of this instrument for use in understanding determinants of interest in careers in STEM. PSS question items are Likert-like with responses on a scale of 1–5, where 1 = strongly disagree and 5 = strongly agree.

This study examined the reliabilities of the PSS scales for students in grades 9–12. The scales used in this study are the same as those presented by the authors of the instrument (see Fig. 17.1). However, the scale referred to as *academic* (confidence) in this research was called *expected self* by the developers of the PSS instrument. This scale was renamed after examination of items for face validity, sometimes referred to as *look see* revealed that the items for this scale relate to students' expectation that they will be academically successful in science classes. Therefore, this scale was renamed *academic* (confidence) by the researcher to prevent this scale from being associated with the e*xpected* possible self-identified by Oyserman and Fryberg (2006), which is associated with expectation or confidence in achieving or attaining a desired self, such as becoming a scientist. The scale referred to as *participation* (in science) in this research was called *strategies* by the developers of the instrument. This name change, based again on face validity of the items in the scale, was intended to clarify that the items of this scale relate to the students' intent to participate in science classes, clubs, and activities, rather than on students' strategies for attaining the goal of becoming a scientist. Internal consistency reliabilities of the PSS *desired*, *academic*, *feared*, and *participation* scales were examined. Cronbach's Alphas ranged from 0.83 to 0.94, considered very good (DeVellis, 1991, p. 85) for the participants in this study. See Table 17.4.

Figure 17.1 shows the instrument that was used for these results; it was used with permission from the authors (Beier et al., 2012).

Scientific Possible Selves Scales and Items.

Hoped for Self

1	I have always hoped to have a job in science one day.
2	Having a job in science one day is very important to me.
3	I expect to go to college and get a degree needed for a job in science.
4	It is very likely that I will get a job in science in the future.
5	I am sure I will do well in a job in science.
6	I expect to have a strong professional career in science in the future.

Expected Self

1	I am confident that I can get better grades than other students in science classes.
2	I think I can get good grades in my science classes.
3	I think I have what it takes to do well in science.

Feared Self

1	I worry that I will not get good grades in science classes.
2	I think about how I don't do as well as others in my science classes.
3	I am concerned about falling behind in science classes.
4	I worry that I won't be able to get a science-related degree.
5	I am afraid that I won't be able to get a job in science in the future.
6	I am afraid people will think it is odd or strange to have a job in science.

Strategies

1	I want to take as many science classes as possible next year.
2	If possible, I would get involved with a science club.
3	If possible, I would want to attend a science camp.
4	I would be interested in participating in a science fair.
5	I read science and science-related stories during my free time.

Fig. 17.1 Survey instrument items (adapted from and used with permission, Beier et al., 2012)

Table 17.4 Internal consistency reliabilities for the PSS scales

PSS Scales	# Items	Item numbers	Cronbach's Alpha	Rating (DeVellis)
PSS: desired	6	1-1 to 1-6	0.940	Very good
PSS: academic	3	2-1 to 2-3	0.831	Very good
PSS: feared	6	3-1 to 3-6	0.918	Very good
PSS: action	5	4-1 to 4-5	0.844	Very good

5 Analysis and Findings

Repeated measures ANOVA was conducted to compare the effect of the field-trip experience, pre/post, on the PSS scales of *desire* (to be a scientist), *academic* (confidence), *fear* (of failing to attain goal), and *participation* (in science) in all participants, by gender, by career interest group, and by above/below mean *desire* groups. If the results of repeated measures ANOVA tests indicated significant differences pre/post, then paired samples, post-hoc protected *t*-test analysis was conducted. The significance level of *t*-test analysis was protected by conducting tests with adjusted significance levels (.05/4, $p < .0125$) for the *t*-test comparison on the four PSS scales. Protected significance levels of *t*-test will correct for possible inflation of a Type-1 error when conducting multiple *t*-tests.

5.1 Science Selves: All Participants

Analysis of data for all participants, by repeated measures ANOVA, revealed possible significant differences on the *academic confidence* and *fear* scales pre-/post-field trip. See Fig. 17.2 for a comparison of means on the PSS scales pre/post.

The repeated measures ANOVA effect of the field trip on academic confidence ($F(1,77) = 9.935$, $p = .002$) scale was examined. Paired, protected *t*-test post-hoc analysis was conducted for significant differences at the $p = .0125$ level. The decrease in mean on the academic confidence scale pre ($M = 4.11$, SD = .846) and post ($M = 3.77$, SD = .957), $t(77) = 3.15$, $p = .002$ field trip was significant at $p = .0125$. This would be considered a medium (.376) Cohen's *d* (Cohen, 1992) effect size.

The repeated measures ANOVA effect of the field trip on the fear of failure scale ($F(1,71) = 5.659$, $p = .020$) was examined. Paired, protected *t*-test post-hoc analysis was conducted for significant differences at $p = .0125$. The increase in mean on the fear of failure scale pre ($M = 2.31$, SD = .866) and post ($M = 2.65$, SD = .990), $t(71) = -2.379$, $p = .020$ field trip was tested. The effect of the field trip on fear was not significant.

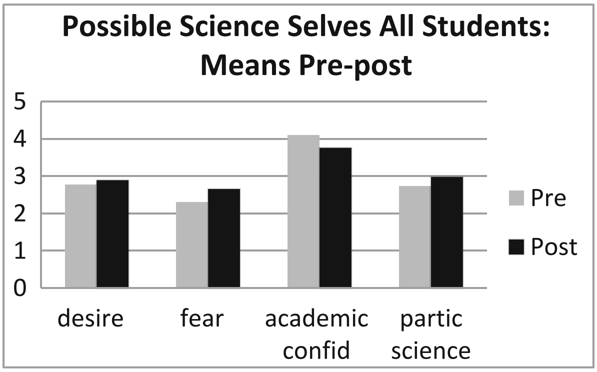

Fig. 17.2 Pre-/post-field trip means for all students responding to the PSS

5.2 PSS: By Gender

Analysis of data for participants by split file for gender, by repeated measures ANOVA, revealed possible significant differences on the *academic confidence* (for men and women) and *fear* (for men) scales pre-/post-field trip.

The repeated measures ANOVA effect of the field trip on the academic confidence scale for male participants ($F(1,45)=5.410$, $p=.025$) was examined. Paired, protected t-test post-hoc analysis was conducted for significant differences at the $p=.0125$ level. The decrease in mean on the academic confidence scale pre ($M=4.06$, SD = .993) and post ($M=3.68$, SD = 1.122), $t(45)=2.32$, $p=.025$ field trip was not significant at $p=.0125$. The effect of field trip on the academic confidence on men was not significant.

The repeated measures ANOVA effect of field trip on academic confidence scale for female participants ($F(1,31)=5.595$, $p=.024$) was examined. Paired, protected t-test post-hoc analysis was conducted for significant differences at the $p=.0125$ level. The decrease in mean on the academic confidence scale pre ($M=4.17$, SD = .593) and post ($M=3.89$, SD = .648), $t(31)=2.37$, $p=.024$ field trip was not significant at $p=.0125$. The effect of the field trip on the academic confidence on women was not significant.

The repeated measures ANOVA effect of the field trip on the fear of failure scale for male participants ($F(1,42)=7.619$, $p=.009$) was examined. Paired, protected t-test post-hoc analysis was conducted for significant differences at $p=.0125$. The increase in mean on the fear of failure scale pre ($M=2.14$, SD = .807) and post ($M=2.65$, SD = .975), $t(42)=-2.379$, $p=.009$ field trip was tested. The effect of the field trip on fear among men was significant at $p=.0125$. This would be considered a medium-to-large (.570) Cohen's d (Cohen, 1992) effect size.

5.3 PSS: By Career Interest Group

Data were analyzed for differences on the PSS scales pre-/post-field trip by career interest group: (1) non-STEM, (2) STEM not engineer, and (3) engineer. Analysis of data for participants by split file for career interest group, by repeated measures ANOVA, revealed possible significant differences on the *academic* (for non-STEM career interest), *fear* (for STEM-not engineer career interest), and *participation* (for non-STEM career interest) on the PSS scales pre-/post-field trip.

The repeated measures ANOVA effect of the field trip on the academic confidence scale, for non-STEM career interest participants ($F(1,38)$ =7.719, $p=.008$) was examined. Paired, protected t-test post-hoc analysis revealed that for participants interested in a non-STEM career, there was a significant difference (decrease) on the academic confidence scale pre ($M=3.95$, SD=.863) and post ($M=3.51$, SD=.920), $t(38)=2.78$, $p=.008$. This would be considered a medium (.493) Cohen's d (Cohen, 1992) effect size.

The repeated measures ANOVA effect of the field trip on the participation in science scale, for non-STEM career interest participants (F 1,39)=7.364, $p=.010$) was examined. Paired, protected t-test post-hoc analysis revealed a significant difference (increase) among non-STEM career interest participants on the participation in science scale pre ($M=2.52$, SD=.859) and post ($M=2.88$, SD=.526), $t(39)=-2.71$, $p=.010$. This would be considered a medium-to-large (−.505) Cohen's d (Cohen, 1992) effect size.

The repeated measures ANOVA effect of field trip on the fear of failure scale, for STEM not engineer interest participants ($F(1,22)=4.806$, $p=.039$) was examined. Paired, protected t-test post-hoc analysis for participants with STEM not engineer career interest revealed that there was not a significant difference on the fear of failure scale pre ($M=2.31$, SD=.905) and post ($M=2.890$, SD=1.02), $t(23)=-2.192$, $p=.039$, at the $p<.0125$ significance level. The effect of the field trip on fear among the STEM not engineer career interest group was not significant.

5.4 Possible Science Selves: By Desire to be a Scientist

Data were analyzed for differences on the *desired, fear* (of failing), *academic* (confidence), and *participation* (in science) activities scales of the PSS pre-/post-field trip by a split (into two groups) at the mean on the *desire* scale, which was 2.73. All participants were placed in one of these two groups: (1) top half by mean desire, and (2) bottom half by mean desire.

Analysis of data for participants by split file for students in the bottom half and top half groups, by repeated measures ANOVA, revealed possible significant differences on the desire (in the bottom half mean desire group) and academic (in the top half mean desire group) scales pre-/post-field trip.

The repeated measures ANOVA effect of the field trip on the academic confidence scale, for participants in the above-the-mean group ($F(1,38)$ =10.779,

$p = .002$) was examined. Paired, protected *t*-test post-hoc analysis revealed that for participants in the above-the-mean desire group, there was a significant difference (decrease) on the academic confidence scale pre ($M = 4.360$, SD = .672) and post ($M = 3.99$, SD = .785), $t(37) = 3.183$, $p = .003$. This would be considered a medium (.506) Cohen's *d* (Cohen, 1992) effect size.

The repeated measures ANOVA effect of the field trip on the desire to be a scientist scale for the below-the-mean group participants ($F(1,35) = 7.903$, $p = .008$) was examined. Paired, protected *t*-test post-hoc analysis revealed a significant difference (increase) on the desire to be a scientist scale pre ($M = 2.064$, SD = .469) and post ($M = 2.472$, SD = .745), $t(35) = -.129$, $p = .004$. This finding would be considered a large (−.656) Cohen's *d* (Cohen, 1992) effect size.

6 Discussion

6.1 Science Selves and Informal Science Learning

As the bar chart for all students indicates (See Fig. 17.2.), perceptions on the PSS desire (to be a scientist), fear (of failure), and participation (in science) were all up, on a scale of 1–5 from pre- to post-field trip for the high-school students in this study. Mean perception of academic (confidence) was down. The analysis of disaggregated data that follows identifies groups that were significantly different pre-/post-field trip. See Table 17.5.

Disaggregation of the PSS data by gender showed that male students were more afraid of failing to reach the goal of becoming a scientist pre-/post-field trip.

Disaggregation of the PSS data by career interest indicated that students interested in pursuing an engineering career did not change significantly on any scale,

Table 17.5 Disaggregated data: significant change on PSS scales

Possible Science Selves Scales	Desire	Academic Confidence	Fear (of failing)	Participation (in Science)
All Students	O	X	O	O
Males	O	O	X	O
Females	O	O	O	O
Non-STEM	O	X	O	X
STEM-not Engineers	O	O	O	O
STEM Engineers	O	O	O	O
Bottom half mean desire to be a scientist	O	X	O	O
Top half mean desire to be a scientist	X	O	O	O

Note: *X* denotes a significant change, *O* denotes no significant change by paired *t*-test analysis, pre/post, reported at the $p < .01$ significance level nor did other STEM majors. The non-STEM group had: (1) a significantly higher intent to participate in science classes and activities and (2) lower academic confidence post-field trip.

Disaggregation of the PSS data by mean desire to become a scientist revealed that students who were below the mean in desire to become a scientist pre-field trip were significantly higher in desire post-field trip. Students who were above the mean in desire to become a scientist pre-field trip were lower in academic confidence post-field trip.

Self-images of possible self are thought to interact in motivating behaviors related to goals, self-regulation, and academic achievement (Oyserman et al., 1995, 2006). Yet possible selves are thought to guide behavior over time when they are both balanced and when there are strategies with associated goals (Oyserman et al., 2004). Oyserman and Fryberg (2006) indicated that desired and feared selves should be studied in conjunction as balancing counterparts. For example, a decrease in confidence of one's academic preparedness or the fear that one may not be a good enough student to attain a desired goal may motivate one to focus more closely on success in school, thereby increasing the likelihood of success in a challenging course of study. The pre/post changes in the PSS for fear and academic confidence are reasonable with regard to the multipart science field-trip experience that was the subject of this study. Exposure to the complexity of a gravitational wave observatory and numerous physical science concepts and applications may have the effect of causing students to wonder if they are adequately prepared for the rigors of applied science. This would be considered positive if the link between desired self and fear causes student regulation of behavior to increase academic preparation. This example of a balancing of desire and feared selves would also be positive if it tends to increase the intent to take strategic action in the form of participation in science. Additional research is needed to determine if the awareness of academic challenges and possibility of failure to attain goals among the subjects of this study is related to the balancing of possible selves, a balancing that is associated with improving the likelihood of successfully attaining the desired goal.

Strategic action towards attaining a scientific self, such as participation in science, was of particular interest to this study as a gauge for understanding connections between self-concept and performance (Cross & Markus, 1994). Students who indicated that they do not plan to seek a STEM career pre-field trip were found to be significantly higher in disposition towards participation in science (classes, clubs, and activities) post-field trip. However, paired *t*-test examination indicated that an increase in mean for participation in science was approaching significance at the $p < .05$ level for all students in this study post-field trip. Additional research is recommended to determine if the increase (all students) of $M = 2.74$, SD = 1.02 pre-field trip to $M = 2.98$, SD = .883 post-field trip, $t(76) = -1.935$, $p = .056$ on the participation in science (classes, clubs, and activities) scale will be statistically significant for other populations or larger sample sizes.

6.2 Technology-Mediated Possible Science Selves

The PSS scales were used by Beier et al. (2012) to examine how students, for whom there is no access to real-world science experiences and mentors, might acquire an interest in STEM career via experience with playing serious video games. Recognizing that it is important to create positive experiences for students early in the school years, researchers examined the role of science video gaming in the middle school classroom. Students reportedly expressed interest in forensic science after science game play. In a study of university student learning with science video games, Mayo (2007) reported comparable learning in traditional engineering classes as compared to equivalent video game versions of a required course.

While the study presented here centered on change in students' possible science selves after a field-trip experience, the researcher also questioned the $n=88$ participants regarding their view on the use of video games for science learning. The students interested in an engineering career, $n=14$, stood out for being significantly different from the non-STEM career interest group in the perception that *video games can help me to learn about the field of science*. Analysis of variance was conducted with Tukey post-hoc for the mean response by three career interest groups: (1) non-STEM, (2) STEM not engineer, and (3) engineer (responses were on a scale of 1–5, 1 = strongly disagree to 5 = strongly agree). An analysis of variance for this data indicated that students with an engineering career goal ($M=3.86$, SD = 1.27) had significantly higher perceptions of learning science with video games than non-STEM majors ($M=2.77$, SD = 1.27, $p=.027$), a medium Cohen's *d* (Cohen, 1992) effect size. The STEM not engineer group ($M=3.00$, SD = 1.44) was not significantly different than the other two groups. This finding indicates that some students have much higher perceptions of being able to learn from interaction with video games than other students. Additional research is required to determine how technology (including gameplay) can be used to support possible science selves and to expand an understanding of determinants to choosing and achieving a STEM-related career.

7 Conclusion

While we do not have conclusive evidence regarding interventions that can be relied upon to increase students' participation in science-related learning (Nixon et al., 2013), there is good reason to believe that informal learning is important to students' desires to like and learn science. Additionally, Cross and Marcus (1994) indicated that there is a relationship between self-concept and performance. Science selves are of particular interest as a tool to gauge changes in students' self-concepts and aspects of performance such as participation. This study indicates that science selves, representing students' self of being a person of science can be strengthened by participation in a science field-trip experience. Findings were that students who did not initially express an interest in seeking a STEM course of study become significantly more positive in their desire to participate in science and students who were initially higher than average in their desire to become a scientist increased significantly in that desire on the PSS factors after a field-trip experience. These findings are in line with the research of Osborne and Dillon (2007), who posit that informal learning of science will advance positive attitudes and participation in science. Additionally, these findings indicate that the PSS (Beier et al., 2012) can assist in examining changes in student dispositions related to their interest and participation in STEM learning.

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Chapter 18
Project Flappy Crab: An Edugame for Music Learning

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Abstract This chapter discusses some possibilities of gamification and remixing processes for music education. It also analyzes the concepts of gamification, mashup/remix and presents its possible usage in education—music teaching—through the development of the project/educational game FLAPPY CRAB. The chapter begins with a brief introduction to the concepts listed above, trying to consider them in the school context. After that, we will make the summary presentation of the music educational game FLAPPY CRAB, a clone of the GEARS Studios *Flappy Bird*, developed for mobile devices and other platforms with the UNITY 3D© game engine. In this chapter we'll talk yet, albeit briefly, about the game engine used in the development of this educational application. This educational game aims to assess the possible impacts that its use has on learning and skill development related to auditory memory, qualitative discrimination of musical sound height (pitch—in the range of an octave with a central point in 440 Hz), visual identification of musical notation symbols and its relative organization according to the grammar rules of traditional music spelling. The game has been tested by a group of approximately 30 teenagers over a period of about 6 months, over which data was collected. In this chapter, we will present a review of the preliminary data collected to date.

Keywords Art education • Awareness • Gamification • Mashup • Remix • Software development

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1 Introduction

In the twenty-first century, the consolidation of a new culture based on ubiquitous digital information, requires a review of practices in search to set a critical update on the educational landscape. It seems indisputable that the cultural paradigm of the twenty-first century is based on digital information. Omnipresent in all aspects of our society, even more so with the huge flexibility introduced by mobile computing devices, portable and powerful. Lightweight digital information surrounds us like a web, enabling communication networks never before imagined. Today we all have the archives of the Alexandria library at a distance of a little touch on the screen of our phone (Cavalcanti, 1996). However, especially in the educational field and in the area of basic education (2nd and 3rd Cycle, in Portugal), a large part of the teaching/learning processes are still based on traditional methodologies, some using artifacts archetypes as outdated as the chalkboard or chalk. Therefore, it is necessary to invest in different knowledge acquisition processes directly related to the new technologies, namely with resort to strategies like the gamification or the remix, given that they are undeniably present as much in the educational processes (formal or informal) as in the context of the cybernetic culture. At this point, students—all children of this time—no longer see themselves in these dated educational processes, little or nothing related to their everyday life practices. It is necessary to research and invest in new methods of knowledge acquisition, especially when directly related to information and communication technologies, in particular using strategies such as the gamification and/or remix, given that both are present at the same time in the educational processes (formal or informal) as in the entire surroundings of modern society.

This chapter aims to bring two major contributions: first, the presentation of a prototype of an educational music game, Flappy Crab, so-called because it is a clone of the GEARS Studios *Flappy Bird*, developed for mobile platforms such as iPhone, Windows Phone (Smartphone), and tablets with the help of the UNITY 3D© game engine. It should be noted that, although developed for mobile platforms such as smartphones and tablets, the game will be published also in a version capable of running on fixed devices such as, for example, desktop computers (desktops and laptops). This version was designed to facilitate the use of Flappy Crab in formal learning environments, such as the classroom or the schools Educational Resources Centers (ERC). Preliminary results of the study will be submitted given that, although still ongoing, we may discern some driving lines; and second, this study proposes to explore all possibilities and advantages that creative pedagogical techniques such as the remix/mashup and gamification can have on the teaching of art education and music, in particular, a very specialized area of human knowledge.

This chapter is organized as follows: the first part will discuss some of the implications that strategies like the gamification or the remix might have on the learning process; in the second part we will make the presentation of the educational game Flappy Crab, featuring storyboard and gameplay, and we will discuss preliminary results collected to date. We will do a brief account of the development software, also referring to the visual programming plugin PLAYMAKER©, HUTONG GAMES©.

In the last part of the chapter, we will overview some proposals for future work, weaving considerations about the impact of this kind of pedagogical activities.

2 Gamification, Remix, and Mashup in Education

2.1 Gamification and Learning

Gamification is a relatively new concept that has garnered considerable momentum over the last years (Deterding, O'Hara, Sicart, Dixon, & Nacke, 2011; Kapp, 2012; Lee & Hammer, 2011). It's a strategy that aims to apply the mechanics of gaming to non-game activities to change behaviors. At its root, the concept applies the mechanics of gaming to non-game activities to change people's performance. When used in the educational field, gamification is the process of integrating game dynamics and game mechanics into learning activities and didactics objects such as tests, quizzes, training exercises, educational games, and others, in order to drive engagement, internal or intrinsic motivation, participation, and processes of self-discovery.

The gamification generates metacognition and self-learning processes, helping to build creative solutions in situations of absence of intrinsic motivation. The intrinsic motivation is a factor of vital importance in all kinds of learning and even greater in musical literacy contexts (Csikszentmihalyi, 1990; Wu, 2014). Gamification aims to combine intrinsic motivation with extrinsic one to raise the self-commitment in the accomplishment of one activity. Intrinsic motivation comes from within, leaving to the user/student the capability to decide whether to make an action or not. This feature develops character traits such as sense of belonging, altruism, competition, cooperation, non-aggression, or love feelings. On the other hand, extrinsic motivation happens when a force or entity outside us induces the user/student doing a certain action or learning process by the promise of a reward, which can be a badge, points, levels, or missions. In our days, the education system already recognizes the power that the strategy of gamification has to improve students' engagement, building processes of metacognition and the potential for solving a variety of problems related to the lack of intrinsic motivation, so important in music learning (Csikszentmihalyi, 1990; Wu, 2014).

With the model of the four factors for the design of educational activities, ARCS, proposed by John Keller (see Fig. 18.1), we can analyze with great acuteness the degree of motivation generated by immersion in gamified activities (Kapp, 2012). This model aims to introduce a methodology based on solving problems in processes of development of motivational educational activities. In this context, we can define game mechanics as the set of rules and rewards that make up game play a satisfying and motivational activity, in other words, these are the aspects that make it challenging and educative, or whatever other emotion that the gamified activity hopes to evoke. These emotions, in turn, are the result of desires and motivations that we could call game dynamics. The most common game mechanics (Lee & Hammer, 2011) include

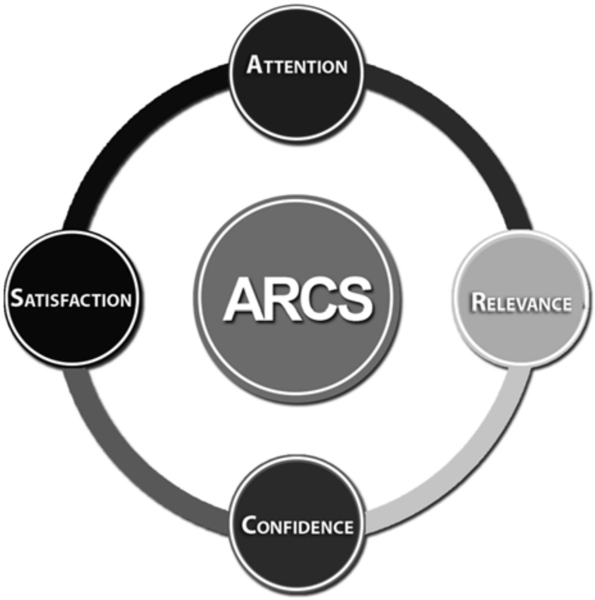

Fig. 18.1 John Keller's ARCS model. *Image source*: http://arcmit01.uncw.edu/erg1602/Glossary.html

- **Points**: studies driven by the University of Chicago are showing that points are fantastic motivators and can be used to reward users/students across multiple levels or dimensions of the gamified activity. In fact, we know that people love to be rewarded and, when interacting with the point system, they feel like they've gained something.
- **Levels**: are often defined as point thresholds, so the students (or users) can use it to indicate a higher status and control access to bonus content on the game.
- **Challenges**, **badges**, **achievements,** and **trophies**: the introduction of goals in an activity makes the students (users) feel like they're working toward something. Normally, the challenges should be configured based on actions that we desire to improve, and rewarding users/students that accomplish reaching certain milestones with badges, achievements, or trophies.
- **Leader boards** or "high-score table": in the context of gamification, high-score tables are used to track and display desired actions, using completion to drive valuable behavior. In intrinsic motivation terms, they are one of the most important features of a game, bringing aspiration factor to the process.

Finally, it should be noted that, in a way, the educational system has always used the gamification in teaching/learning processes. Evaluating written tests by a quantified system can be considered as a kind of high score; so, in a very literal sense, the school has always used gamification in their processes by applying scores on assignments that can be considered points; and also, according this perspective, the graduation is a level achieved and a diploma is a form of granting a badge of confidence

(Lee & Hammer, 2011), However, this game-based system doesn't seem very engaging for the students; nonetheless, we think that perhaps the education process and particularly music learning could be improved by adding the game factor through technology.

2.2 Remix and Mashup

The modern society is characterized by individuals who are no longer willing to be merely passive receptors of data contents, but they want also produce, by cutting, sampling, paste or jam with content, in order to create something which is distinctive of their own social and creative innovation (Katz, 2009). The techniques of remix and mashup can be traced to the first experiences of great artists like Pablo Picasso (www.tate.org.uk/context-comment/blogs/work-week-bottle-vieux-marc--glass-guitar-and-newspaper-pablo-picasso) but they gained importance and visibility with the rise of the internet and new digital technologies, which have made easy re-using and remixing the existing cultural contents. In fact, we live in a culture of convergence, which we can see in aspects such as the personalization of video games and on the amendment of audiovisual content that circulates in the cloud, through techniques such as the remix and the mashup.

An artifact uses the remix technique when it has been altered from its original state by the addition, removing, and/or creatively changing the item parts. Therefore, the only feature of a remix piece is that it appropriates with artistic freedom other materials and pieces to create an artifact completely new. When associated with music and songs, the modern remix has its roots in the Jamaican dance hall culture of late 1960/early 1970, with musical forms such as the ska, the reggae, or the dub (all three derived from Jamaican music). Such techniques, formerly reduced to a supporting role as artistic expression, grew in importance and visibility with the advent of the internet and new digital technologies, since these media facilitated very much the mixing of cultural content.

Mashup refers to the combination of contents or functionality from more than one external source to create a new entity and can be considered as the remix practices that use one or many materials, media, or other sources for creating new artifacts trough alteration, re-combination, manipulation, and copying. In doing so, the sources of origin may still be identifiable yet not perceived as the original version. The techniques of remix and mashup are extremely appreciated by digital natives (Kapp, 2012), so, in the present, they are extensively practiced (Buzato, Silva, Coser, Barros, & Sachs, 2013).

In the music educational game Flappy Crab we have used remix and mashup techniques regarding the game idea—cloned from an addictive mobile game—and the visual design, created from clipart images obtained from an online open source database (https://openclipart.org/). The characters in the game have been carefully selected to constitute a form of artwork of approach (the musical figures/quavers with human faces). These temporary use mechanisms aim to help the young pupil to understand the relative space/time as well as make eye contact with the musical notation (McPherson & Gabrielson, 2002). This educational application intends to motivate the student to advance his learning in a playful way and may be used at any time and space and not necessarily in school context.

Although the game prototype is still in a very early development stage, the concept was introduced to a set of thirty students aged between 9 and 12 years; these users have considered the gameplay excellent and the interface very intuitive.

3 The Project Flappy Crab

The process of gamifying a didactic object lies on the objectives to be attained, since these determine the entire creative process. Therefore, prior to development of the educational game Flappy Crab, we have accomplished a thorough literature review, namely:

- Viewing and performing the analysis of several mobile games to determine the most appropriate game model to sustain the storyboard that we had imagined.
- Once the game model was chosen we had to decide which game engine (application development) to use; After analyzing various applications, we have chosen UNITY 3D©, given its robustness and flexibility, but above all by the introduction of new capabilities for 2D games from version 4.3.
- We also had to consider very carefully the didactic contents related to the learning of music that would have a greater advantage in being worked out with the techniques of gamification. Eventually we decide by music spelling-related aspects, discrimination of heights (pitch) and auditory memory.
- And, finally, we researched proactive methods of teaching and learning, especially if related to techniques of gamification and remix.

Since in Portugal the subject of music education is mandatory only in the 2nd cycle of schooling, 5th and 6th grade, respectively, we decided to build the game for a target audience between the ages of 10 and 12 years old. The game has as its main objective to promote the learning of music, by means of facilitating the input of users/students in a state of flow. According to this theory and the model proposed by Csikszentmihlyi, during an experience, the person is so involved with the goal-driven activity that nothing else seems to matter (Csikszentmihalyi, 1990). The mechanics of the game was aimed at optimizing informal learning processes, especially related to the symbols of the notation/spelling of music (rhythmic figures, notes, staves, and grammatical punctuation), discrimination of heights of sounds between the 261 Hz (C_4) and 523 Hz (C_3) and auditory memory.

Once established the type of game, the game engine, the target skills and didactic typology, it has become necessary to develop a story (the storyboard) to make the game attractive but not too simple, inconsequential, or childish. Since the sea is an entity always present in the Portuguese collective imaginary and culture, we have chosen a scenario that mimics the coastal landscape; over the course of the game, the scenario changes depending on the progression of the main character. Linking up with this scenario, the goal of the player is to traverse the world's oceans to find the legendary music island.

Basically, the music educational game Flappy Crab aims to promote music learning based on the Csikszentmihalyi's Flow model. The target audience for Flappy Crab places itself between the ranges of 10–12 years old from the 2nd Cycle of Basic Education. This educational application focuses on the usage of mobile computing devices, gamification, and remixing to enhance student participation and encourage learning in music and art education.

3.1 Game Mechanics, Storyboard, and Interaction

The ground beneath the idea of gamifying a didactic object determines the workflow. Considering the game mechanics of the educational game, Flappy Crab planned to enhance informal learning of musical note, we did include the seven design concepts proposed by Priebasch (2014), as follows:

- The game includes visual measuring experience and progress by means of the score counter.
- Rapid feedback provided through the dynamic progression, by means of sound warnings when the player gains or lose points.
- Multiple short-term goals, that leads to a bonus level.
- Rewards for effort and task completion, by the inclusion of a bonus level always the player anteing a certain sore (Wu, 2014) and
- An element of uncertainty because the player never knows exactly what will be the bonus level form (Priebasch, 2014).

Flappy Crabe is a side-scrolling mobile game featuring 2D graphic style, established on a series of individual sprite sheets. The aim is to guide the flying red crab named Flappy, which descends and runs continuously to the right, between each set of oncoming Sargasso sea plants without colliding with them, which otherwise will restart the game over and o'er. At the same time, fishes and the mermaid's bonus with one music figure hidden inside continuously moves towards the player at a different velocity rate. The crab briefly flies upward and in front each time the player taps the screen, consequently, is a game easy to learn but difficult to control.

The game is shown in three scenarios. The input menu (Fig. 18.2) will make the game distribution, holding into account the levels of choice. Once the game has started, by pressing an interactive button, the musician/student can always revert back using the function "Quit," available in all scenarios.

At the first level are presented to the player the rhythmic figures in the form of subsidized items to go collecting while avoiding the obstacles (Sargasso sea plants). These items are introduced along the level with different speeds and random positioning (Fig. 18.3). The player character scores 25 points on each Sargasso sea plant and fish bonus he passes through: when the score achieves a predetermined number,

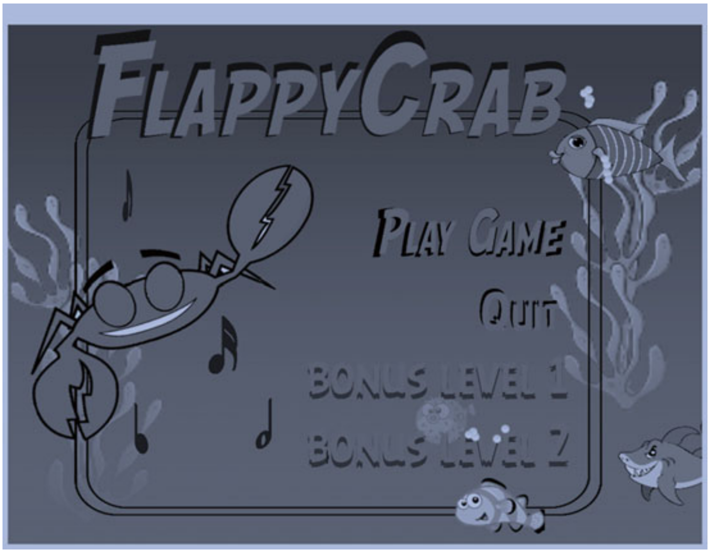

Fig. 18.2 Edugame FLAPPY CRAB: input menu screen

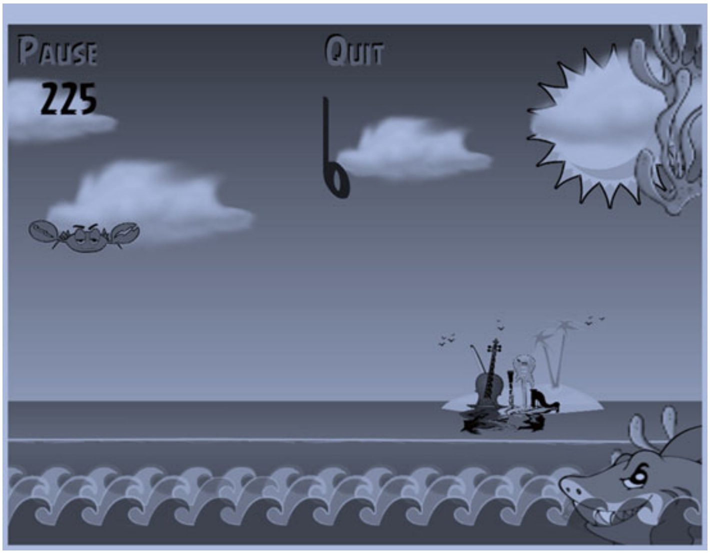

Fig. 18.3 Edugame FLAPPY CRAB: first intermediary level

the game jumps automatically to a bonus level. When the player reaches a score equal to 500 points, qualifies to the first bonus level, with a positive reinforcement delivered with a sound message. Bonus levels have different mechanics, since training aims the recognition capability of absolute pitch in association with melodic memory. Here, the player must replicate a given melody (musical sound sequence) with seven musical sounds hidden in several buttons on the game interface. Once the task is done, the player returns to a level with the same previous mechanics and so on.

Bonus levels can be of two types:

- In the first, when starting the game, the user/student finds himself confronted with the audition of a random series of four (or more) sounds of different heights, that he has to memorize and repeat by pressing one of the four shells (which creatively simulate the keys of a musical instrument) of contrasting colors [red (C_4), yellow (E_4), blue (G_4), and green (D_5)] that are in the foreground in the scenario. Every time the player repeats successfully a series of sounds, the difficulty level will rise, and it proposes a new series, adding a new sound, meaning that if the repeated series had four sounds, the following will have five and so on (Fig. 18.4). This level encourages the auditory memory and discrimination of sounds of different heights, skills that are not intuitive and constitute one of the greatest barriers for all those who want to develop the ability known as *absolute pitch*. At this level, it is possible to track the student's cognitive development for the two previously described capabilities in a quantitative and qualitative way.
- The second bonus level proposes a little tune, spelled according to the rules of musical writing pattern that the player/student will have to rewrite, also from a simulated keyboard with shells. This time, the user has only the eight sounds of the diatonic scale (without accidents, sharps, or flats) and the visual/aural example given to it when he/she starts the level. The player/student can perform as many attempts as necessary to complete the task; once this is done, an auditory reinforcement, marks the passage to a new intermediate level. This level,

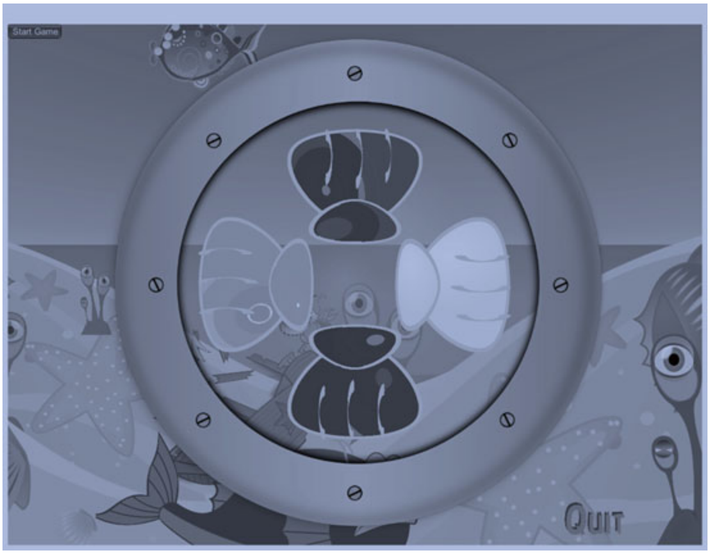

Fig. 18.4 Edugame FLAPPY CRAB: first bonus level

Fig. 18.5 Edugame FLAPPY CRAB: second bonus level

although keeping the mechanisms described above, will always have a different scenario, in order to encourage the user to experience the game storyboard and get emotionally involved with it (Fig. 18.5).

The interaction with the game is done directly through a little touch on the screen of mobile devices or with a click of a pointing device (mouse) on desktop computers (desktop or laptop). This gesture keeps the character (Flappy) in constant motion to the right, avoiding contact with any other object of the game, otherwise it's forced to restart the level. The number of players' lives are unlimited, functioning as a revival arcade game type (with a mechanic similar to the TAITO's Bubble Bobble), where the player cannot save the progression and has to restart whenever dies. No prerequisites are required to play, just a little adjustment period for some possible variations related to the sensitivity of the mobile or fixed devices used. In the first test of usability (Nielsen, 1999) we have implemented, was found that, on average, none of the players had trouble understanding the mechanics of the game, as this mimics a well-known mobile application of GEARS Studio. All levels focus on music education and learning, and aim to encourage the development of abilities of pitch discrimination, auditory memory, and musical spelling. As already noted, the gameplay of the application isn't conditioned by previous knowledge, although familiarity with the symbols of musical spelling, lexicon, and Western music may be a factor to consider for the emotional surroundings and gameplay. Throughout the game, help is available, but must be expressly requested, since the goal is to make the player/student practice skills of autonomy and self-capacity of reasoning.

3.2 Game Engine

The project was developed with the UNITY 3D® game engine, v. 4.3 in C # programming language with the help of Hutong Games® plugin, Playmaker® v. 1.6.6. The game "FLAPPY CRAB" has versions for mobile platforms with operating systems, Android, iOS, Windows, ARM and standalone (in 1024×768 format) for PC, Mac, and Linux. Audio objects used were edited to Wave and Mp3 format with the free distribution program Audacity®.

The UNITY 3D® game engine, free distribution in the retail version, features a simple and easy-to-learn interface where the various tools available appear explicitly and intuitively. With an area of work divided into different Windows (views), which can be rearranged according to user preferences, the UNITY's interface offers five main spaces; the scene area, the space where you can see the game development, the area called *hierarchy* where are listed the game objects, the area of the *project* where are being organized all folders and files created and the window called *Inspector*, from which you can change the features of the objects in the game: the only parameter that accompanies all objects is the *Transform* tool, with information about the position, rotation, and scale. Later, we can add and manipulate components such as audio capability, rigid body properties, or the typology of the final rendering.

In the latest versions, this game engine acquired the ability to edit objects in a 2D environment, including the ability to import graphical images (here called sprites); this feature has facilitated the revival game development, especially emulating the playful typologies of years 80 and 90 of the twentieth century. On the other hand, the UNITY 3D© provides the possibility to export the applications developed directly for platforms such as Android or Windows ARM—Windows Store without mediation of any other API. Due to its visual editor and the ability to export directly to other platforms, using the graphics engine UNITY 3D® accelerated considerably the development of the educational game FLAPPY CRAB, proving to be suitable to the needs of production required by the storyboard and the goals initially outlined.

4 Presentation and Analysis of Preliminary Results

Usability pre-tests were carried out and data were collected with the standard questionnaire System Usability Scale (SUS) (Brooke, 1996). After treating the information, the results were as follows:

- Satisfaction [q1], 95.2 %
- Ease of use [q2, q3, q4, q8], 95.2 %, 95.2 %, 90.5 %, 100 %
- Ease of learning [q7] 100 %
- Functionality [q5], 81.0 %
- Interface consistency [q6], 95.2 %
- Navigation efficiency [q9] 100 %
- Trust [q10]. 81.2 %

The individual tests were conducted informally, and the data have been collected by a direct observation process. The tests were carried out over a period of 6 months and the test group remained the same, in order to observe the evolution of the acquisition of learning skills we set out to achieve. At this moment, we can infer results of behavioral parameters such as motivation, satisfaction, and the individual average game time. We can also see a trends perspective with regard to the skills acquisition degree in terms of auditory memory and different height discrimination, to the extent that such data is quantifiable in nature.

We emphasize that, during the implementation of the tests—we have performed 15 surveys, one per week, in a 45-min class—it was noted that, over time, users have shown a growing learning curve (Fig. 18.6).

The results are more visible if we look at the week average translated in a curve of an exponential trend (Fig. 18.7).

From these preliminary data, we can conclude that there are positive developments concerning the skills observed, especially in the field of auditory memory and discrimination of heights because users/students doubled their initial capacity for both parameters.

Regarding motivation, were observed student's strong indicators of membership: students seem to like a lot of the activity and, from the first session, repeatedly ask when they would have a new chance to play. Therefore, although at an early stage of development, this pedagogical artifact—the game FLAPPY CRAB—seems to demonstrate a significant impact on the development of specific skills in the field of music education.

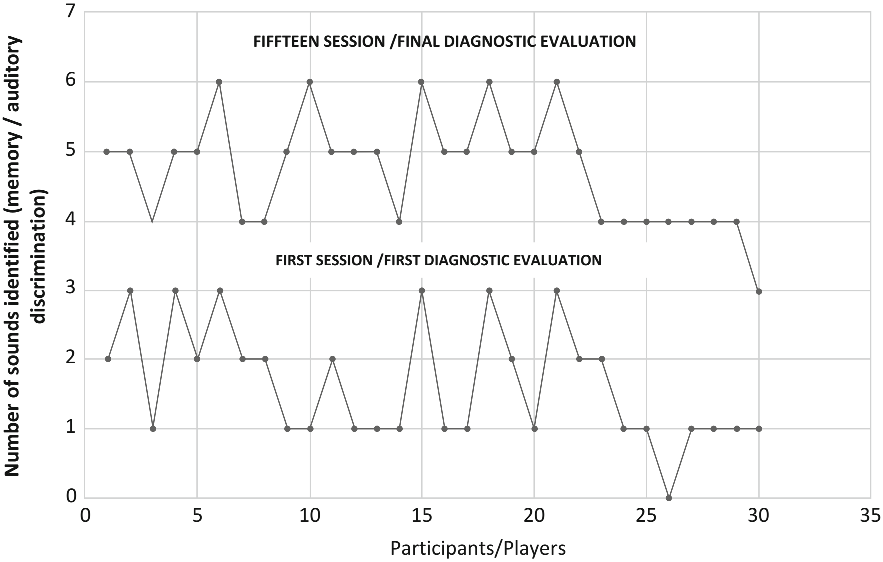

Fig. 18.6 Results concerning the ability of memorization and discrimination, referenced by participants/players

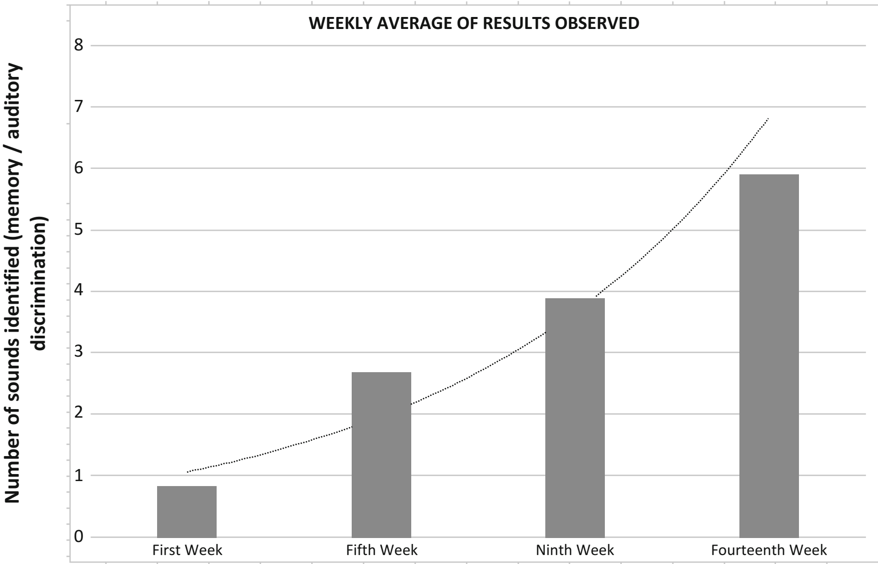

Fig. 18.7 Results concerning memorization and discrimination after 15 surveys

As future work, we will continue to collect data in order to consolidate or infer the above mentioned preliminary findings.

5 Conclusion

With the emergence of the internet and mobile games, gamification and mashup techniques are also becoming increasingly important in the educational system. Games have now achieved a new paradigm where their purpose is no longer for entertaining only but also for educating. In fact, games can offer interactive learning activities that can foster creativity and long-term knowledge. Understanding how and why gamification works, in what contexts, it is most effective, and what the limits are of this approach will be highly useful in sorting out the useful bits. On par with the development of gamification, the mashup/remix phenomenon is yet new and can be considered as a coevolving process of user-generated media content. In a society where the information flow is ubiquitous, the educational process, namely at the level of aesthetic expression, needs to engage the learners' awareness to the possibility of re-combining digital media available and make the respective re-interpretation, in a process where even the undesirable copy and paste method can morph into a creative foundation.

Drawing on the experience of gamification and mashup/remix techniques, this explorative chapter makes the presentation of a prototype educational game, called

Flappy Crab, that emulates the famous GEARs game and aims gamifying the learning process of music formal reading and increases the auditory memory capabilities. The educational application FLAPPY CRAB was developed with the game engine UNITY 3D®. We have also discussed the implications of strategies such as the gamification and remix while teaching methods, as well as other techniques in the construction of learning objects, in particular in the specific field of music education, *sui generis* in many aspects of the nature of his writing and also by its entity metaphysics and timeless. In fact, music education touches on all learning domains, namely the development of specific skills (psychomotor domain), the acquisition of theoretical knowledge related to acoustics, the art history and aesthetics (the cognitive area) and especially the affective domain, at the level of the development of capacities like the willingness to receive, internalize, and share what is learned, including the increased sensitivity and music appreciation. In fact, the music, as language and visual arts, is a unique feature to the humankind.

Once presented with the preliminary results of the study seems to be possible to discern some driving lines, indicators of developments at the level of skills of memorization and auditory discrimination, and, so far, users tend to some increasing learning curve. As future work, we're going to propose to continue the already started testing in order to confirm or infer the results obtained.

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Chapter 19
Educational App Creation for the Cathedral in Freiberg

An Interdisciplinary Project Seminar

Cindy Kröber and Sander Münster

Abstract This project seminar aims at creating and evaluating a manual for interdisciplinary projects as part of a learning process. Working together, pedagogues and students from different disciplines within the humanities and sciences of different universities assess tools and recommendations for successful collaborations while developing an app for the visitors of the cathedral in Freiberg. As part of the project, the students gain expertise in project management and apply their theoretical knowledge to a real object and assignment. The introduction to techniques from other disciplines as well as the requirements needed to create an app for users unfamiliar with the cathedral and basic principles of art history and linguistics is a true challenge which complicates their work for the app. The seminar provides an option for students to gain practical experience before entering the job market. The outcomes and contributions serve as a reference. The results of the project seminar and the manual may be assigned to other interdisciplinary projects.

Keywords Cross-disciplinary learning • Project-based learning • Team teaching

1 Introduction

A major aspect related to research and presentation of Cultural Heritage objects is their visualization for the public. Thus, media for such purposes are mostly created within projects by interdisciplinary teams (Münster, 2013). The common terms "Digital Humanities" or "eHumanities" refer to the adaptation and

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application of applied computer science for research and presentation within culture and humanities (Hockey, 2004). Protagonists contributing to such applications in Cultural Heritage are usually (a) scholars from the humanities, who provide the content and knowledge about the research objects, (b) engineers and computer scientists who acquire and process data for the visualizations, (c) experts in media education who develop a concept to present the findings and visualizations to the audience, and (d) technicians implementing the design and presentation concept. While these scenarios are increasingly relevant for practical work, for example when establishing exhibitions in museums, digital editions or 3D reconstructions, they currently play just a minor role in academic education of historians or media developers (Gradl & Henrich, 2011). Moreover, project success and efficiency rely highly on quality and experience related to both the application of professional knowledge and interdisciplinary cooperation skills.

For more than a decade it has been argued that in higher education, additional to acquiring specific expertise and knowledge in their discipline, students also need to attain skills necessary for employment (Fallows & Stevens, 2000). The shift towards an approach which will focus more on the development of practical skills and not exclusively on academic skills indicates that employers prefer graduates with communication skills and teamwork experience (Donelly & Fitzmaurice, 2005). This reflects an existing need to introduce students to real-world experiences and applications which they will benefit from when entering the job market.

Based on the assumption that skills for interdisciplinary project work are best acquired within a practical project (Strobel & Van Barneveld, 2009), a guide for such projects might encourage more teachers to use them as a practice-related educational strategy. To overcome the lack of project work-related experiences in education, especially for historians, the intention was to develop, investigate, and verify recommendations and guidance with the help of a research seminar that focuses on cross-disciplinary teamwork.

A cooperation where every participant—students and teachers alike—contributes their knowledge and ideas to the subject of the research as well as the educational course was the purpose and goal of the project. The development and observation of the project seminar as a collaboration between students and pedagogues of a variety of disciplines ensures the practical relevance and the transferability concerning other interdisciplinary projects. Reflections and explication of methods and results during the seminar were fundamental to ensure the success of the project and the manual as a final outcome.

A short outlook presents the idea to incorporate s*crum* into student team projects. Scrum is a method used, for example, in software engineering where several people need to structure and organize their work for one project. It might help with difficulties in team project-based learning.

2 Educational Principles

2.1 Teaching Approaches

Different teaching strategies aim at active involvement and interaction of students and teachers in order to enhance learning experiences as well as development of skills for self-directed learning, collaboration, and problem-solving.

2.1.1 Project-Based Learning

A well-known approach to acquire skills dealing with complex and multi-perspective problems is project-based learning (PBL), i.e., learning by doing, originally introduced by Dewey (Dewey & Dewey, 1915). By definition, PBL is an individual or group activity taking place for an extended period of time and with a specific result like a product or presentation which drives the planning, production, and evaluation process (Donelly & Fitzmaurice, 2005). It is an instructional, student-centered strategy in which students determine what they need to learn" in order to solve nontrivial, real-world problems and where teachers act as facilitators to foster both problem-solving and learning progress (Barrows, 2002). Usually, more than one approach or answer will lead to solving the problem and students are encouraged to seek out multiple sources of information and evaluate different methods. While performed by student work groups as teams during project-based learning, skills like a cooperative ability, critical reasoning, creative thinking, responsibility, and communication are promoted (Lee & Lim, 2012; Moursund, 2003). In comparison to other learning designs, PBL promises a greater satisfaction and level of engagement of students as well as a higher level of long-term retention of acquired competencies (Strobel & Van Barneveld, 2009). Generally, lectures introduce similar real-world examples for illustration purposes as PBL, but without any experience the understanding of students is relatively limited.

PBL is particularly effective when combined with computer technology. Technology-supported PBL and multimedia technology-assisted PBL are the two categories that refer to the use of technology for project work (Chang & Lee, 2010). Technology and tools which are useful for communication, research, project management, and collaboration are part of technology-supported PBL. Multimedia technology-assisted PBL includes the use of multimedia for presentation purposes. Any advances in technology may support PBL but the fundamental principles of communication remain the same. Possible issues with a mandatory involvement of technology in the project comprise technical difficulties with soft- and hardware, a lack of prompt technical support, and a varying interest and use of the tools provided.

Potential problems of PBL may result for example from non-equal contribution of teammates to the final outcome and a fair negotiation of individual contributions as well as a high management load and a lack of transparency for teachers about project group activities and social constellations (Lee & Lim, 2012). Preparation of the project's layout, allocation of tasks and resources, as well as a more complex assessment of the project's results must be considered. A lack of pedagogical training and recommendations for teachers in higher education is also amongst the reasons for a hesitant adaptation of PBL, as efficiency relies highly on a well-prepared design for the project, especially when multiple disciplines are involved.

2.1.2 Team Teaching

Team teaching is a well-established way to encourage multiple perspectives, promote dialogue, increase participation, and improve evaluation and feedback (Anderson & Speck, 1998). There are several degrees of collaboration between teachers. At a low level, teachers might plan the content of a course but teach and evaluate separately. The highest level of collaboration demands co-planning, co-teaching, and co-evaluation of the course (Perry & Stewart, 2005). Especially with multiple disciplines involved, team teaching on a high level of collaboration is effective because the "interactive nature of team teaching may be a potential source of intellectual stimulation and cognitive development for learners as well as faculty" (Hatcher, Hinton, & Swartz, 1996). Two or more teachers sharing teaching expertise and engaging in reflective dialogue with each other has several advantages. A promotion of teamwork and communication is highly important for interdisciplinary project work (Chang & Lee, 2010). While co-teaching the teachers consider each other's ideas and demonstrate respect for the integrity of the other, which is an essential aspect of teamwork. Developing a task together and including multiple perspectives will improve contextualization and therefore help reflect on a bigger picture of the assignment.

Successful team teaching depends on experience, personality, working style, and beliefs about learning (Perry & Stewart, 2005). The teachers become more conscious of the processes involved in teaching as well as potential problems and needs for solving the project's assignment.

2.2 Learning Conception

For the students, the end product may be the driving force to collaborate, but for the teachers the general learning objective of the project is to support a development of several skills for learners. Team project-based learning with multimedia addresses not only complex tasks but also the learning conception and related learning objectives for the project which are based on clues from various explanation models.

2.2.1 Gain Experience

While knowledge in academic learning mostly focuses on explicit and theoretical knowledge, its practical implementation in complex scenarios is seldom part of academic education. For the benefit of practical application, the knowledge should be organized around problems rather than disciplines (Cordeiro & Campbell, 1995). According to a problem-solving process, solution quality highly depends on prior real or imagined experiences of individuals for a certain situation (Tsoukas, 2006) and the availability of extant patterns for a solution (Simon, 1972). That way the students are able to adapt behaviors associated with certain situations and problems. Moreover, these schemes highly depend on disciplinary prerequisites and a professional qualification (Goodwin, 1994) and are fundamental for cognitive load theory (Collins, Brown, & Newman, 1987; Hatcher et al., 1996) as an explanation model for the cognitive processes of learning. Implications for our project are to set learning objectives for gaining practical expertise on application and interpretation of academic knowledge, performing cross-disciplinary teamwork and applying gained expertise to a certain use case, consecutively. Another main challenge for the students is to define an original task, a level of support, and required outcomes.

2.2.2 Development of Teamwork-Related Competencies

Each part of the cathedral was handled by a cross-disciplinary student team (2–5 members). Following implications from cognitive load theory, during the early stages of cooperation, a more intensive guidance and supervision of groups as well as a predefined schedule are required. This will help to reduce cognitive workload caused by team-building processes and organizational learning as well as the formerly described acquisition of personal competencies (Argyris & Schön, 1978; Wegner, 1986). Moreover, as suggested by project management, self-organization of teams has to be monitored continuously (Turner, 1999). Due to these reasons, research assistants ensure the dissemination of information, questions and progress between the teachers and student teams.

2.2.3 Enhance Abilities for Interdisciplinary Communication

Practice-based competencies and experience are closely related to implicit knowledge (Polanyi, 1966). A major challenge for teamwork and interdisciplinary cooperation is the expression and explication of knowledge (Schön, 1983). Another closely related challenge of knowledge transfer processes in cross-disciplinary projects results from differing disciplinary terminologies. While more sophisticated code patterns like language require a synchronization of individual interpretation and understanding (Wilkes-Gibbs & Clark, 1992) architectural structures as natural (Tversky, 2002), "everyday experienced" visual media are highly suitable to build a common ground for interdisciplinary communication (Münster et al., 2014). Architecture can support a communication of more abstract and sophisticated concepts like a construction order as a boundary object (Star & Griesemer, 1989).

2.2.4 Enable Competencies to Create Knowledge Media

The project's final result of the students' work is an app for smartphones which provides visitors with information on the cathedral's architecture. A transfer of individual and team mental models into multimedia content is challenging in many ways. As highlighted for visual and textual media by Mintzberg and Westley (2010), mental processing for a creation of media differs greatly and different media are suitable for different information. While the targeted application can contain various media, the competencies for selecting, processing, and combining of media need to be developed. Another issue is related to the adjustment of the proposed application for visitors. Due to this process, a role switching takes place and student work groups work as designers of learning media proposed to others, anticipating user needs for usability and user experience and instructional design.

3 Layout of the Project

The project seminar is a student project where an app is created within an educational project with the outcome of a manual for interdisciplinary student projects. Supported by the *Hochschuldidaktisches Zentrum Sachsen* (Saxon Centre for Teaching and Learning in Higher Education), this project seminar is a cooperation between the Institute of Art and Music Studies and the Media Center of the *Technische Universität Dresden* as well as the Chair for German Literature and Medieval Studies of the *Technische Universität Chemnitz*. The project started in April 2014 with 30 student participants at both bachelor and master levels. A final presentation of the results was set for October 2014.

Students involved in the project belonged to the fields of art history, linguistics, and geoscience. The students of the humanities researched aspects of architecture within the cathedral and its purpose for communication with the visitors. Visualizations like reconstructions and animations by the geo-based students emphasized the results.

Based on processes of the working world, the seminar follows the typical layout of a project with a timeline and milestones as well as formative evaluation techniques. A basic timetable (see Fig. 19.1) sets deadlines for different tasks within the project seminar. As the seminar's components are dedicated to knowledge acquisition and educational instructions, the courses and study trips are designed to fit the project's timetable. The students work in interdisciplinary teams to cover and carry out their assignments. Alternating periods of project work and reflection about the proceedings and their results form a recurring pattern. Additional to the courses, a learning management system is used for file sharing and feedback.

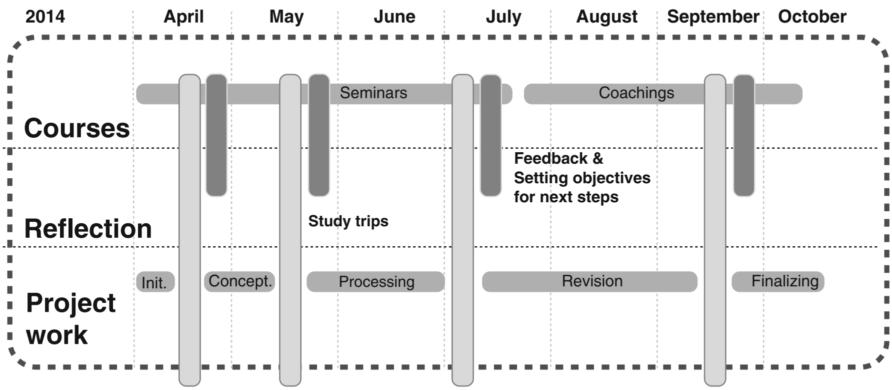

Fig. 19.1 Project seminar layout

3.1 Role of the Teachers and Research Assistants

Successful learning within projects is highly dependent on the driving assignment. Does the project's task aim at applying, interpreting, and assessing theoretical knowledge and does it support teamwork and therefore the development related to skills for communication and collaborative work (Barron et al., 1998)? The project specifications should be more detailed and matured than usual in lectures (Donelly & Fitzmaurice, 2005). Hence, one of the main tasks for teachers before the project start is the elaboration and design of an assignment for each student team, taking into account the interdisciplinary approach, the content of the seminar and the multimedia presentation within the visitor's app as the final result. Being a research seminar, new findings and approaches to the topics and objects of the cathedral in Freiberg were anticipated and sample projects from the fields of eHumanities served as examples to show students what was expected. A paper with preliminary resources and literature as well as subject-specific, authentic impulses and questions from humanities was proposed. A special focus was placed on suggestions, settings, benefits, and necessity for interdisciplinary team work. The paper was a cooperation of all teachers involved and also took into account the topics of the different courses. The collaboration of the teachers during the design of the project helped to avoid redundancy within the seminars (Hartenian, Schellenger, & Frederickson, 2001). The project's agenda and the papers supplied a sufficient advertisement for the seminar.

Within the courses and study trips, the teachers took over the role of facilitator, mentor, and guide for individual students as well as teams. With the project's progress, the teachers put more emphasis on encouraging the students to trust their own instincts and also consider ideas from fellow students. They helped to establish a reflective perspective for research and relevance within each student.

Usually, standardized tests are the overall choice to judge academic achievement (Thomas, 2000). They support the comparability of results and allow the evaluation of a large number of participants. Individual and diverse results have to be valued differently. The assessment of the project's success considered the performance and contribution of every student as well as the final result and was discussed by all teachers. With the help of team presentations and individual consultations during the whole project, the teachers were very aware of the progress and involvement of each student.

Team teaching is most effective in demonstrating interdisciplinary and collaborative work and its benefits and calls for a good preparation and close cooperation of the teachers. Coordinating the schedules of three teachers, three research assistants, and 30 students from six different study programs proved difficult. Taking into account that the people involved came from two different universities in two different cities and the research object itself was in another city required a well-prepared project plan.

The high workload of management and monitoring tasks during the project seminar calls for the involvement of assistants (Dunlap, 2005). The main tasks for research assistants was to set up and organize the project plan including the timeline and ensure the dissemination of information, questions and progress between the teachers and student teams. They provided personal guidance and supervision for the teams as well as a detailed project guide through the learning management system. A competent assistant should be available for each discipline involved or required. They maintain contact with the teams in order to detect progress and problems and pass on any information to the teachers and other assistants.

A major draw for the students was the publication of results as a visitors' app. To ensure the integrity of a research seminar in higher education, all contributions had to go through an authentic revision process by the teachers before being released on the website. The research assistants worked on an appealing presentation with scientific standards.

3.2 Role of the Students and Student Teams

Students were very interested in the seminar as it promised project-based learning on an authentic task, introduction to eHumanities and therefore other disciplines, and the possibility to contribute to a valuable application.

The content and its visualizations for the cathedral app were carried out by teams with students from different fields of study. Team project-based learning is very common in engineering and geoscience, whereas students in humanities usually work on papers by themselves. Hence, expectations and experiences with teamwork were different. The student–student interaction fosters and demands an active participation and engagement of each student within the team (Lee & Lim, 2012). With the help of acquired project management skills the students had to plan and supervise the project's tasks and timetable within the group. Developing a common ground and language, taking on responsibility, as well as supervising and motivating each other were challenges that needed to be overcome. A variety of tools in the sense of technology-supported PBL and technology-assisted PBL were available for the students, and the teacher actively encouraged their use. Every student took over the role as mentor for their own discipline while identifying possibilities other disciplines may provide.

The students had to identify and communicate what they needed to learn in order to solve the assignment successfully (Casey, 1996). A reduction of content to relevant information for the app was very much invoked by students when considering the preparation of content for cathedral visitors.

Additional to working on the app, the students were also involved in creating the guide for interdisciplinary projects through their feedback.

3.3 Courses

Each of the three cooperating partners offered a course for knowledge-building in their field of expertise as well as skills in project management. Certain methods were introduced and evaluated. The students were welcome to visit all seminars but the one fitting their study program was mandatory. The teachers certified successful participation for students from other disciplines.

The courses contained regular seminars in the beginning and were followed by coaching opportunities and discussions with student groups as the project progressed. The topics of the course mostly focused on requirements necessary for working on the app. Previously acquired theoretical knowledge was channeled and adapted in order to help solve the assignment. The students heavily influenced the courses by pointing out current issues and needs.

3.4 Study Trips

Four study trips to the cathedral in Freiberg and a public presentation of the app were intended. Every trip focused on a certain task or project step, such as the introduction of the teams and the research objects, exploration of the object, data acquisition, and presentation of the results. The teams planned and prepared for the study trips by distributing the work, developing a concept, and executing and reviewing the work. Short presentations of the teams' progresses were set at the beginning of the trip and allowed the students to reflect on their work and view it in context with other group achievements. A workshop for reflection and feedback as well as an evaluation concluded it.

The second week-long trip was important for data acquisition and intensive examination of the object. Students could seek individual counseling with teachers. They had to set and plan team meetings und make appointments with teachers.

During the trips the teachers engaged in team teaching in order to encourage the students to allow multiple perspectives, seek dialogue with teammates, and increase participation.

3.5 Evaluation and Feedback

Evaluation is a way for collecting and interpreting information that relies on monitorable methods with a process and assessment-oriented dimension (Kromrey, 2001). In order to gain insight into the success and acceptance of the seminar, the study trips were accompanied by evaluations to provide "frequent opportunities for formative assessment by both students and teachers" (Barron et al., 1998). The formative character of the evaluation intends to draw and verify consequences in order to improve the project design. With regard to the manual for interdisciplinary project seminars, it was important to promptly identify issues and find satisfying solutions. The overall goal was to determine and evaluate the quality and suitability of the teaching concept in order to recommend it for higher education.

Research assistants prepared and analyzed the evaluations including perspectives of all participants—students and teachers alike.

Due to the project layout, the evaluation was split into several investigations and possibilities for feedback to cover a variety of aspects and allow everyone to participate. Questionnaires helped to perceive challenges promptly. Online survey tools or handouts were used depending on the situation for the evaluation.

The focus of the first survey was to gather information on expectations and experience of the students especially concerning (interdisciplinary) teamwork and familiarity with certain technology. It was carried out before any courses had started and enabled the tutors to get to know the students and estimate a level of support. Satisfaction with knowledge-building in the courses and interdisciplinary group work was the attention of the second questionnaire. A third survey was meant to acquire information on satisfaction with guidance, project progress, and time management. In order to estimate a general success of the project and compare it to other seminars, the last survey was a standardized one. The questionnaires were used to perceive challenges and issues. Findings were categorized, prioritized, and possible solutions were considered by research assistants.

The recurring study trips set a frame for feedback via discussions. The group discussions functioned as qualitative interviews where subjective opinions and individual experiences were taken into account as well as general directions for all participants and an explorative approach of issues were distinguished. Therefore, the discoveries and possible approaches were presented and openly discussed by everyone. Engagement and directness of all participants were surprisingly high, but it was also possible to contribute anonymously. Comments and feedback by all participants were considered and turned into recommendations for interdisciplinary student projects relying on team project-based learning.

4 Discussion and Results

The project's progress concerning the app as well as the manual was positively reviewed by all participants. A special appeal was provided by the concept of a research project carried out with a variety of disciplines involved. Thanks to the high degree of individual supervision by the teachers and assistants, the general dedication to the project exceeded the dedication in common seminars by far.

The teachers involved prefer to work with proper objects in their actual environment because it helps the students to scrutinize and consider different angles and points of view (Donelly & Fitzmaurice, 2005), a quality easily forgotten in a seminar room.

Out of all the information they had gathered during research, the students had to select, process, and combine what they wanted to present to visitors of the cathedral. The adjustment to a user with little previous knowledge concerning the cathedral or art history in general was a challenge. The teachers pointed out that giving more thought to the final content of their contribution was a very positive experience rather than writing every finding down without taking into account its relevance.

The students noted the importance of advertising the project correctly. It needs to be emphasized that it is a research project which differs greatly from common projects concerning the approached and the expected results. Uncertainties about the involvement of all disciplines regarding a time budget and assignments caused reluctance amongst some students. Suggestions for coping with the concern are to keep the involvement of every discipline transparent and include it in the advertising of the seminar.

The seminar has shown that working in teams is still a novelty to students from humanities. Because of study routines and the focus on research, they are used to working alone. Dividing the workload and relying on teammates proved to be a challenge, but the experiences during the project changed their attitude towards team projects positively.

The students from geo-based disciplines were very much used to team work because of many experiences during surveying and studying, but they lacked the ability to explain possibilities to their teammates. Especially in the early stages of the project, the students needed guidance to find a common ground and not lose patience with each other. Therefore, support by research assistants was essential to form and encourage team work. An excessive use of technology for communication proved insufficient. The students did not know each other beforehand and needed to get to know the person behind the unfamiliar discipline. Personal contact, especially in the beginning, should be encouraged. A course where all participants attend apart from the study trips might prove helpful. It could focus on project management and help the teams set up a basis for communication, time management, and a group hierarchy as opposed to dealing with it during the other courses separately. An expert on project management could take over this course and thus lighten the teacher's workload and ensure quality in that area.

Many good ideas formed once the students took the time to explain requirements and possibilities to each other. Because of differing disciplinary terminologies, the students had to develop strategies for the expression and explication of knowledge as well as the exchange and assessment of results. Visual media proved a good communication ground.

Taking over as mentors of their discipline built up their confidence within the group and helped them to face and solve problems collectively. Students on a master's level adjusted to this role more easily. They had more insight concerning techniques and propositions of their disciplines.

A major issue for the teams was delays caused by dependencies. Visualization of the app relied on findings by teammates which caused frustration for the students who had to wait, and pressure and reluctance for the ones who had to deliver and were unsure if the research was complete.

While setting up the concept of the seminar, the engagement of the students was underestimated. The students independently prepared advice, tutorials, and instructions based on knowledge from individual coaching by the teachers. This occurred especially for the course on visualization. By sharing it through the learning management system, the other participants adopted the idea. The engagement of students to help each other will be promoted and demanded in future seminars.

Students underestimated the evaluation and decision on certain software and strategies for e.g., data sharing in a sense of technology-supported PBL and were not satisfied with their solutions. Learning from mistakes was noted as very valuable for future projects.

4.1 The Visitor App

The app for the cathedral has proven to be a very nice incentive for the students. Seeing that their work and effort will be put to further use and be appreciated by visitors had increased the student's motivation and built pressure to excel. The publicly accessible app may also be a reference for future job applications.

The app is a website and can be viewed under www.freiberger-dom-app.de. The content is available in German only. External partners set up the content management system and the design of the website. Both can be used for future projects. Applying a responsive design allows the use of different (mobile) devices to visit the website. This was important because the cathedral does not own any multimedia devices. The staff of the cathedral very much supported the project and was willing to allow surveying techniques like terrestrial laser scanning to collect data of the research objects.

4.2 The Manual for Interdisciplinary Project Seminars

The manual provided for teachers interested in executing a similar seminar is a draft including recommendations and workflows for preparing, executing, and evaluating the project. It states the initial situation and motivation concerning interdisciplinary teamwork in higher education. It provides recommendations and instructions for the preliminary arrangements like distribution of assignments amongst staff, advertisement of the seminar, timeline, software and tools, and evaluation concept. To-do lists allow a quick estimation of tasks for certain stages of the project. Material of the initial seminar is provided and can be adapted. The role of the teachers is described extensively to help them adjust to the new role as facilitator.

The *Hochschuldidaktisches Zentrum Sachsen* (Saxon Centre for Teaching and Learning in Higher Education) administers and distributes the manual. Currently, it is only available in German. Further projects may be used to complete and improve the recommendations.

4.3 Scrum as an Approach for Team Project-Based Learning

To cope with some of the challenges related to team project-based learning like identification of requirements concerning knowledge, skills, techniques, and tools, coordination of tasks within a team, delays in progress and transparency of individual contributions for the teachers, a new technique is very promising. Scrum is a procedure model from agile software development. It contains strategies for sequencing of work processes, adjustment and prioritization of objectives, and documentation of progress (Schwaber & Sutherland, 2013). The participants break down the assignment into work packages, distribute them, and expose dependencies. They meet regularly and report on advances and problems (What have I done so far? What will I do next? Where are the problems?). This allows fellow teammates to estimate progress and identify needs for support. Some tasks may depend on others and communicating and knowing the advancements of others will help avoid delays and plan further steps. Presentation meetings with supervisors will be used to show the overall progress of the project.

For education, the benefit of this method is the possibility for teachers to monitor any progress and not just evaluate the presentations. They can estimate further needs for teaching content and know about the involvement of the students in the project.

A future seminar is intended to include Scrum as a method for team project-based learning and evaluate its success and suitability.

5 Conclusion

Focusing on the learning scenario through a perspective of problem-solving, creating a representation of problems requires deeper integration of ideas and a more intense coordination between team members (Mintzberg & Westley, 2010). Even if visual communication strategies would foster the building of a common ground for interdisciplinary communication (Münster et al., 2014) and promote long-term retention of learning outcomes, other learning scenarios may ease the entry and accessibility for students. The experiences and knowledge acquired during the project equips the students with a variety of essential skills for a career entry. However, seminar projects require a high degree of supervision and significant time to be carried out (Barron et al., 1998; Blumenfeld et al., 1991). Coordination by, e.g., research assistants, is just as necessary as a well-prepared layout of the project. Moreover, it is necessary to focus on questions or problems that drive students to encounter (Thomas, 2000). Featuring a collective purpose as the final result of the project is a very effective way to motivate students and help overcome difficulties by working together.

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Chapter 20
An Approach to Designing and Implementing Intelligent Tutors in Immersive Virtual Environments

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Abstract This paper discusses the issues in designing intelligent tutors, and presents an intelligent tutoring system developed for an educational bioscience game, called Virtual Cell, which is an immersive 3-dimensional environment that helps students learn Cellular Biology. A comprehensive and adaptable goal system capable of meeting the requirements of students with different knowledge levels is proposed.

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Our solution is characterized by: (1) supporting multi-user collaborations and competitive play; (2) leveraging novel data mining techniques specifically tailored to meet our needs; and (3) incorporating mini-games as complementary tutoring resources. The overarching aim is to make informed tutoring decisions, and improve student learning and efficiency, as they work through each module in the game.

Keywords Collaborative learning • Exploratory technologies • Intelligent software tutors' student-centered learning

1 Introduction

Research in active learning environments includes implementing live simulations for exploration and discovery that engage learners while treating them to a plausible synthetic experience (Slator, 1999). Live means multi-user collaboration and interaction, competitive play, and intelligent software tutors. However, designing and implementing a learning system incorporating all these features is challenging. Ideally, systems provide modelling of effective strategies, intelligent scaffolding, and accurate feedback (Graesser, Chipman, & King, 2007). In recent years, Immersive Virtual Environments (IVEs) have offered an excellent opportunity for science education with cutting-edge technology such as 3D visualization and simulation. Meanwhile, game-based teaching and learning have gained increased attention. However, the tutoring found in existing games is not at the same level: tutors typically consider only the students' current actions, overlooking past activities where important play patterns may be hidden. In the real-world, a good instructor teaches different students with different strategies, and thus, different advice might be given based on the severity of the mistakes made. This work proposes to classify past mistakes by integrating data mining techniques to analyze student play history, in order to uncover important play patterns to create focused, individualized tutoring strategies for students. We have implemented an intelligent tutoring system capable of accomplishing this goal and deployed it in Virtual Cell (Borchert et al., 2013; Kariluoma et al., 2013; Yan et al., 2013), a virtual, multi-user space where students fly around a 3D world and practice being cell biologists in a role-based, goal-oriented environment (Borchert et al., 2013; White, McClean, & Slator, 1999).

1.1 Context

There have been a number of serious games and platforms developed for educational purposes, such as the Visual Program (Juell, 1999) for AI education, the ProgrammingLand MOO (Hill & Slator, 1998) for computer science education, the On-A-Slant Virtual Village (Hokanson et al., 2008; Slator et al., 2001) for anthropology education, and the Geology Explorer (Saini-Eidukat, Schwert, & Slator, 1998, 1999; Schwert, Slator, & Saini-Eidukat, 1999; Slator, Saini-Eidukat, & Schwert, 1999; Slator, Schwert, & Saini-Eidukat, 1999) for geosciences and earth science education. In the following, we give an overview of those games and platforms.

The Visual Program project (Juell, 1999) employs the Virtual Reality Modelling Language (VRML) to provide an environment where a set of visualizations of Artificial Intelligence (AI) programs are developed to help students do active learning. For example, to teach the traditional AI searching processes such as Depth First Search (DFS), Breadth First Search (BFS), and Hill Climbing Search, some animations showing the search paths of the algorithms have been made. However, there are no intelligent tutors available for students, which has limited the educational efficacy of this project.

The ProgrammingLand MOO (Hill & Slator, 1998) was developed to aid in programming classes and used a port of the original LambdaMOO (Curtis, 1998) server as its own server. It provides students with a number of entryways to Virtual Lectures: one example lecture is the Language Foyer that is the entryway leading to one of several mainstream programming language tutorials. However, all of the educational materials are text-based and the way in which students learn is more like an individual study without any guidance.

To teach middle-school students about the Mandan (a sedentary native North American tribe) and their culture, the On-A-Slant project employed state-of-the-art 3D computer visualizations that immerse viewers in the past, and provide them with a means to travel through time and walk through the site as it existed in the eighteenth century (Hokanson et al., 2008; Slator et al., 2001). Software agents called "avatars" were developed to assist students in their learning. But the agents acted mainly as a narrator instead of a teacher due to the inability to respond to the student's actions.

The Geology Explorer (Saini-Eidukat et al., 1998, 1999; Schwert et al., 1999; Slator, Saini-Eidukat, et al., 1999; Slator, Schwert, et al., 1999) creates a role-based immersive virtual environment where students learn fundamental concepts of geology and deductive scientific methodology by assuming the role of a geologist. In this learn-by-doing environment, students are assigned different learning goals, e.g., a primary goal which requires them to identify one specific mineral in the virtual planet, and a secondary goal which asks them to identify any rock or mineral during the process of their exploration. Three types of tutors were designed to help them complete their goals. The Exploration Tutor comes to the student when a goal has been missed. The Equipment Tutor recommends instruments and equipment necessary for field experiments to be correctly done. The Geology Tutor acts as both a geologist and a teacher who points out mistakes made by the student and helps identify the possible reasons. For example, if the student has incorrectly guessed the name of a rock or mineral, the Geology Tutor informs the student of incomplete tests that may help in identification, why the student's guess was incorrect, and how the student's guess is different from the rock or mineral that was observed (Borchert et al., 2001). However, this tutoring process is based on a task model to support inference about student states that, while qualifying as intelligent tutoring is not designed to provide individualized remediation.

1.2 Intelligent Tutoring

Due to the issues with software tutors in the aforementioned games, WoWiWe Instruction Co has developed Virtual Cell, an immersive 3-dimensional environment that helps students learn Cellular Biology. This simulation models a 3D plant cell and embeds the students in an environment where they pilot a miniature submarine that allows them to explore a plant cell. It focuses on providing an authentic problem-solving experience that engages students in the active learning of the structure and function of the biological cell (Slator, 2006). Virtual Cell provides distinct modules covering standard topics that can be applied to a biology curriculum. Intelligent software tutors are available to guide the students during their game play. The tutoring system designed for the Virtual Cell has overcome the above mentioned tutors' shortcomings by incorporating data mining techniques to uncover student play patterns and offer individualized tutoring.

The intelligent tutors discussed in this work are deployed in the WoWiWe Instruction Co. version of the Virtual Cell. Four modules of the Virtual Cell have been completed: the Organelle Identification module populated with subcellular components where students are required to identify the nucleus, endoplasmic reticulum, Golgi apparatus, and so forth using deductive scientific approaches (reasoning, analysis, assay, etc.); the Electron Transport Chain (ETC) module which demonstrates the respiration process and requires the student to understand the movement of hydrogen and electrons when ADP is converted into ATP in the mitochondria; the Photosynthesis module which teaches students the process of photosynthesis by asking them to repair damaged photosynthesis reactions in the chloroplast; and the Osmosis module which teaches the movement of solvent molecules through a semi-permeable membrane (such as a cell membrane). In each module of the Virtual Cell game, a guide is on hand to direct players to their next task, and a tutor is available when students struggle in accomplishing their learning goals.

1.3 Project Overview

First, we design a comprehensive goal system that is adaptable to students with different knowledge levels in a role-based, goal-oriented immersive virtual environment (IVE). The learners are assigned specific tasks in accordance with their learning goals covering various components and organelles of a cell in the first module. The difficulty of the goals increases progressively as the student works through each task, and the level can be adapted to meet the requirements of educating different students such as high school students and college undergraduates.

Second, to provide more individualized tutoring to students who have difficulties in accomplishing their learning goals, we propose a data mining model to analyze student play history, aiming to discover non-obvious but important patterns to help make better tutoring decisions. For example, two kinds of tutoring are provided based on the specific type of mistake made: blind tutoring is initiated if the discovered patterns show the mistake was made by chance, while oriented tutoring is undertaken if the uncovered patterns implied the student may have fundamental confusion between the two concepts.

We also developed a library of problem-oriented knowledge to help locate the confusions that students may have as they explore in the Virtual Cell. Supported by this library, tutors act as subtopic experts, monitor student progress, and match the current student's actions to previous students' actions, allowing the tutor to ask relevant questions that may be preventing the student from moving forward.

Last, we employ ontology mapping techniques to improve the data quality of the student play history and model student learning activities. For example, tutoring decisions depend to a high degree on the type of diagnostic assay the student is performing. Therefore, the agents developed in this work are capable of offering more individualized and problem-oriented tutoring.

2 The Goal System

There are four modules in the Virtual Cell: the Organelle Identification (ID) module, the Electron Transport Chain (ETC) module, the Photosynthesis module and the Osmosis module. They are designed to help students improve scientific reasoning and their understanding of the scientific method (Borchert et al., 2010).

2.1 ID Module Goal System

The ID module is designed to provide an introduction to game play, with the student tasked with making hypotheses, gathering data in the form of required experiments, and finally identifying seven different organelles contained in the cell. These tasks represent seven parallel goals (identifying the nucleus, endoplasmic reticulum, Golgi apparatus, mitochondria, chloroplast, ribosome, and vacuole) which together form the structure of the goal system in the ID module. Figure 20.1 illustrates the goal system. A goal is completed if its corresponding tasks are all completed. For example, to complete the "NucleusIDGoal," two tasks need to be completed: the "DNAAssay" task which requires the player to perform the marker assay for DNA synthesis, and the "NucleusReport" task which requires the player to file a report to confirm the hypothesis. Note that the "DNAAssay" task must be completed before the "NucleusReport" task.

Each goal is represented by a series of tasks to be completed. Through performing the tasks, students learn the scientific/deductive process to follow in order to confirm the identification of an unknown substance, in this case an organelle. For example, a student might be asked to identify the Golgi apparatus in the Virtual

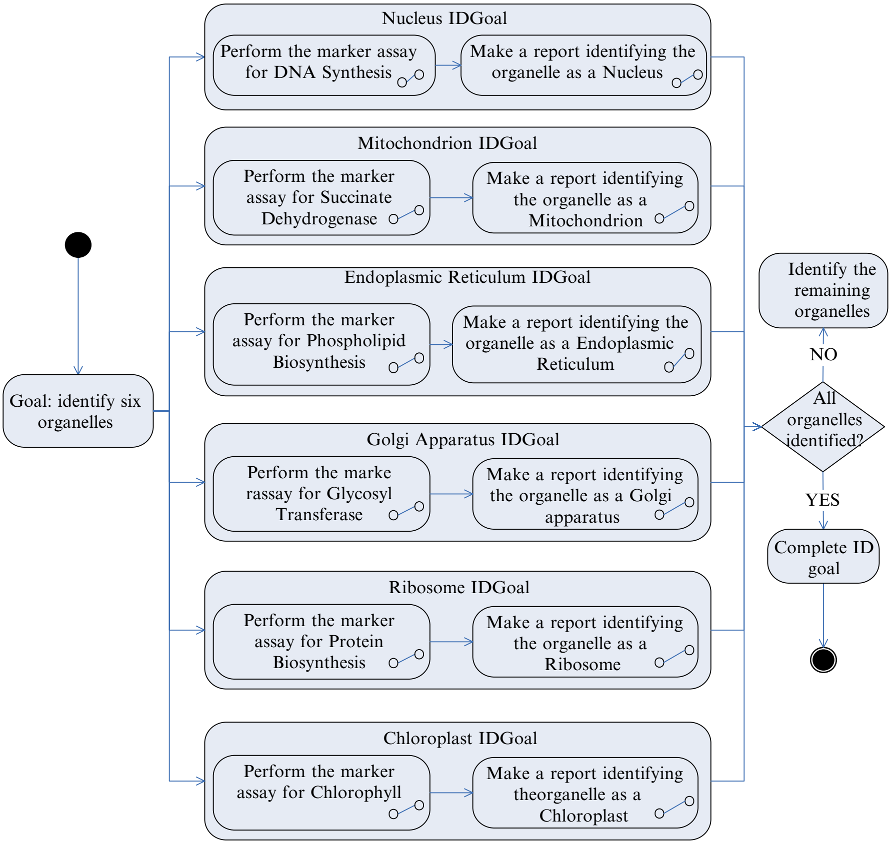

Fig. 20.1 Goal structure for the ID module

Cell. To complete this goal, three tasks must be performed, and the goal of identifying this organelle cannot be completed if any of the tasks are skipped or performed in the incorrect order.

- ***Task 1:*** Hypothesize that an unknown organelle is a Golgi apparatus and scan it.
- ***Task 2:*** Perform the marker assay for glycosyltransferase to confirm the hypothesis.
- ***Task 3:*** Make a report identifying it as a Golgi apparatus.

Upon each successful completion of the designated task, the player is prompted to advance to the next, until all of the tasks for this module are completed. Figure 20.2 gives a screenshot after the player has correctly completed the glycosyltransferase assay task. In Fig. 20.2, a user has just performed an assay for glycosyltransferase on a golgi apparatus, and found some. Another player is in the submarine in the upper left.

Fig. 20.2 The ID module simulation

2.2 ETC and Photosynthesis Goal Systems

The ETC module introduces the player to the electron transport chain and cell respiration by first presenting a healthy mitochondrion, and then guiding the player to a damaged mitochondrion. The player is then required to repair the damaged ETC by accomplishing three tasks.

- ***Task 1:*** investigate possible reasons for the cell's low ATP production.
- ***Task 2:*** repair the damaged electron transport chain.
  - ***Task 2.1:*** Hypothesize the broken ETC complex.
  - ***Task 2.2:*** Fire the appropriate substrate at a complex to determine if it is actually broken.
  - ***Task 2.3:*** Purchase a new version of the broken complex from a ribosome.
  - ***Task 2.4:*** Replace the broken complex with a new one.
- ***Task 3:*** File an incident report.

There are six complexes involved in a functional ETC, as well as a healthy supply of the "raw material" substrates: succinate dehydrogenase, hydrogen, and oxygen. Any one of the complexes could be broken which would bring the ETC to a halt. As remediation, a substrate pointed at the proper complex will jump-start the ETC from that point up until the broken complex is encountered. Figure 20.3 shows the simulation inside a mitochondrion. While watching an animation of the electron transport chain, another player (pictured to the right in Fig. 20.3) fires an oxygen molecule at the chain to see what happens.

Fig. 20.3 The ETC simulation inside a mitochondrion

The photosynthesis module is designed to teach one of the most important biochemical processes in plants. Its goal structure is similar to the ETC module except for the final task; the player is required to repair an inactive section of the chloroplast to produce ATP. The detailed goal structure of the photosynthesis module is shown in Fig. 20.4. A goal is completed if its corresponding tasks are all completed. For example, to complete the "ViewHealthyOrganelle" goal depicted in Fig. 20.4, the player must enter a healthy organelle first, and then view an educational animation. After that they learn how to use substrates to test organelles by firing an available substrate into the chloroplast, and finally exit the healthy organelle.

Figure 20.5 illustrates the photosynthesis simulation inside a chloroplast. A beam of light is about to hit the Photosystem II complex depicted in Fig. 20.5. A second player is exploring in the middle right portion of the screen.

To make a game suitable for students with different backgrounds e.g., high school students and college undergraduates, the tasks or goals in the ETC and photosynthesis can be adjusted. For example, in the photosynthesis module, one task is to let students gather the needed substrates to improve the health of the cell. It is obvious that the more missing substrates, the harder the task. Many students know that CO_2 is necessary in the photosynthesis process. But that photons serve as tools to shake electrons free from chlorophyll, and move energy through the rest of the electron transport chain, is more esoteric knowledge. Therefore, the conceptual difficulty of the task of collecting necessary substrates could be decreased by adding protons to the student's inventory at the beginning.

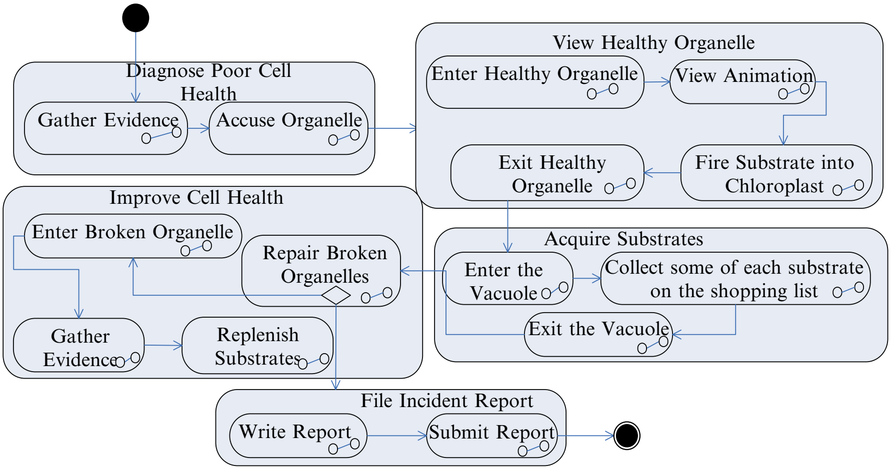

Fig. 20.4 Goal structure for the Photosynthesis module

Fig. 20.5 The photosynthesis reaction in process

2.3 Osmosis Goal Systems

The students enter the Osmosis module through a Golgi apparatus. The Osmosis module aims at teaching the general water movement in plant cells. The students need to understand that solvents (e.g., water) and solutes (e.g., ions and molecules) try to equalize across a semi-permeable membrane. The goal system of this module is designed by presenting two compounded problems to the students.

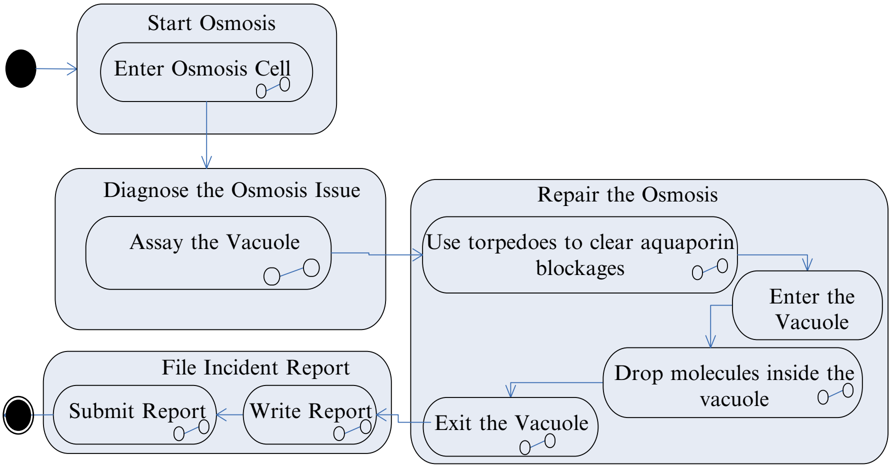

Fig. 20.6 Goal structure for the Osmosis

First, there are physical blockages in the plasmodesmata in the cell membrane which need to be cleared so that water can flow into the cell. Second, the cell is currently isotonic with the environment, and thus no water is flowing. Accordingly, some molecules need to be dropped into the vacuole to break this equilibrium so that water can flow back in.

Figure 20.6 gives the goal structure of the Osmosis module. Module A goal is completed if its corresponding tasks are all completed. For example, to complete the "Repair the Osmosis" goal, the player must first clear a certain number of plasmodesmata blockages, enter the vacuole to drop enough molecules inside it, and finally exit the vacuole. Specifically, three tasks are required to be completed to reactivate the ceased osmosis process.

- ***Task 1:*** Investigate why the current osmosis process has been interrupted.
- ***Task 2:*** Fix the osmosis issue.
  - ***Task 2.1:*** Clear the plasmodesmata blockages with torpedoes. As shown in www. 20.7, some plasmodesmata blockages are preventing water from flowing into the cell, and the current task for the player is to use torpedoes to clear those blockages so that water is able to flow back in.
  - ***Task 2.2:*** Enter the vacuole.
  - ***Task 2.3:*** Drop enough molecules into the vacuole.
- ***Task 3:*** File an incident report.

Fig. 20.7 The osmosis simulation—two players examining a plasmodesmata blockage (foreground) in the cell wall impeding the flow of water into the cell

3 Intelligent Tutors

From the perspective of intelligent tutoring systems, the agents of interest must fundamentally support models of the knowledge of a domain expert and an instructor (Slator, 1999). We maintain software tutoring should not only consider current activities, but also should be aware of past performance, in order to give contextualized, individualized tutoring.

3.1 Knowledge Base

We maintain various information resources in the library of the game. First, based on a concern for information canonicity and coverage, we integrate the relevant biological knowledge derived from our content experts into the backend knowledge base. Students can easily use the toolbox provided in the game to navigate to the game's online encyclopedia, using it to find desired information. Second, multimedia educational materials are incorporated to complement the system's existing knowledge, e.g., animations introducing the process of electron transport and photosynthesis. Students can actively study these materials at any point in the game. Or in another scenario where the player is stuck, problem-oriented and individualized knowledge will be offered as often as needed. This kind of knowledge, like non-obvious student play patterns, goes beyond domain-specific knowledge, and constitutes another significant aspect that helps in customizing the tutoring for individuals. In addition, mini-games that go along with each lesson module are developed for situations where students finish early or where they have trouble understanding lesson concepts. For example, the mini-game designed for the ETC module teaches ATP production by requiring the student to re-orient complexes to correct positions so that ATP can be steadily produced.

3.2 ID Module Tutors

There are currently four modules in the Virtual Cell. The first is the Organelle Identification (ID) module, where students need to identify seven organelles correctly to accomplish their learning goals. During this activity, play history is recorded by the system which serves as important data for determining the type of tutoring to be provided at later stages in the game.

3.2.1 Modelling Method for Capturing Learning Activities

To model student play history, we define a student profile which is essentially a set of related concepts that together represent the student learning activities. This model is inspired by the closed text mining algorithm (Srinivasan, 2004). To further differentiate between different concepts, semantic type (ontological information) is employed in profile generation. Table 20.1 illustrates part of the semantic type—concept mappings. Here, each student profile is defined as a vector composed of a number of semantic types.

$$profile(Stud_i) = \{ST_1, ST_2, \ldots, ST_n\} \tag{20.1}$$

Table 20.1 Semantic type—concept mapping

Semantic Type	Instances (Examples)
Organelle	nucleus, endoplasmic_reticulum, Golgi_apparatus, mitochondrion, chloroplast, ribosome, vacuole
Correct Report	correct_report_no_assay, correct_report_correct_assay, correct_report_incorrect_assay
Incorrect Report	nucleus_as_ mitochondria, endoplasmic_reticulum_as_ chloroplastvacuole_as_ Golgi_apparatus
Assay	DNA_synthesis, succinate_dehydrogenase, phospholipid_biosynthesis, glycosyl_transferase, protein_biosynthesis, chlorophyll

Where ST_i represents a semantic type to which the related concepts representing the student's learning activities belong. Each semantic type can be further expanded by an additional level of vector composed of concepts that belong to this semantic type and relevant to the student's play activity.

$$ST_i = \left(w_{i,1}m_1, w_{i,2}m_2, \ldots w_{i,n}m_n\right) \tag{20.2}$$

Where $m_j \in ST_i$ represents a concept under the semantic type ST_i and $w_{i,j}$ denotes its weight. When generating the profile we replace each semantic type in (20.1) with (20.2). To compute the weight for each concept in (20.2), we employ a variation of the TF*IDF weighting scheme (Jin & Srihari, 2006) and then normalize the weight under each semantic type:

$$w_{i,j} = s_{i,j} \,/\, highest\left(s_{i,j}\right) \tag{20.3}$$

Where $l = 1, 2, \ldots, r$ and there are in total r concepts for ST_i, $s_{i,j}$ = the number of occurrences of m_j, where $m_j \in ST_i$. By using the above three formulae we can build the corresponding profile for any given student. To summarize, the procedure for building a student profile is composed of the following four major steps:

- ***Step 1:*** Concept Retrieval: retrieve all relevant concepts from the student play history.
- ***Step 2:*** Semantic Type Employment: each concept is associated with and grouped under one semantic type (e.g., Assay, Incorrect Report) to which it belongs.
- ***Step 3:*** Weight Calculation: for each concept, a variation of the TF*IDF scheme is used to calculate the weight (i.e., $s_{i,j}$ as shown in Formula 3).
- ***Step 4:*** Weight Normalization: the weight of each concept is further normalized by the highest concept weight observed for its semantic type as given in Formula 3. Within each semantic type, all concepts are ranked according to the normalized weights.

3.2.2 Tutoring Strategies

The generated profile represents the student's play history and potentially includes valuable patterns to be mined and utilized. Each time the student conducts an activity, e.g., performing a DNA synthesis assay on a nucleus or mistaking a mitochondrion for a chloroplast, the profile is updated (i.e., the weight of each concept in the profile is recalculated) to reflect the up-to-the-minute learning status of the student. The tutoring system makes tutoring decisions based on the discovered pattern frequency (i.e., weight computed using formula

3). If the pattern frequency does not reach the threshold predefined in the system, blind tutoring will be offered, otherwise oriented tutoring will be launched. Here blind tutoring means the tutor provides general conceptual information like the structure and composition of a plant cell, and does not further investigate the student's learning problem (e.g., "did the student perform an incorrect assay?"). By contrast, oriented tutoring indicates the tutor starts to explore the student's past activities, such as "the student is mistaking what for what?" and then attempts to offer the best problem-oriented advice.

For example, a student may have confusion between a nucleus and a mitochondrion. If this mistake has been captured frequently enough to reach the threshold set in the tutoring system, a student-oriented tutoring session (with a specific focus on explaining the nucleus and mitochondria) will be activated. Figure 20.8 demonstrates the detailed remediation strategies for incorrect reports. Once an incorrect report is filed, the system will examine the player profile and calculate the weight of the misidentified concept. If its weight exceeds the threshold defined in the system, either blind or oriented tutoring will be activated.

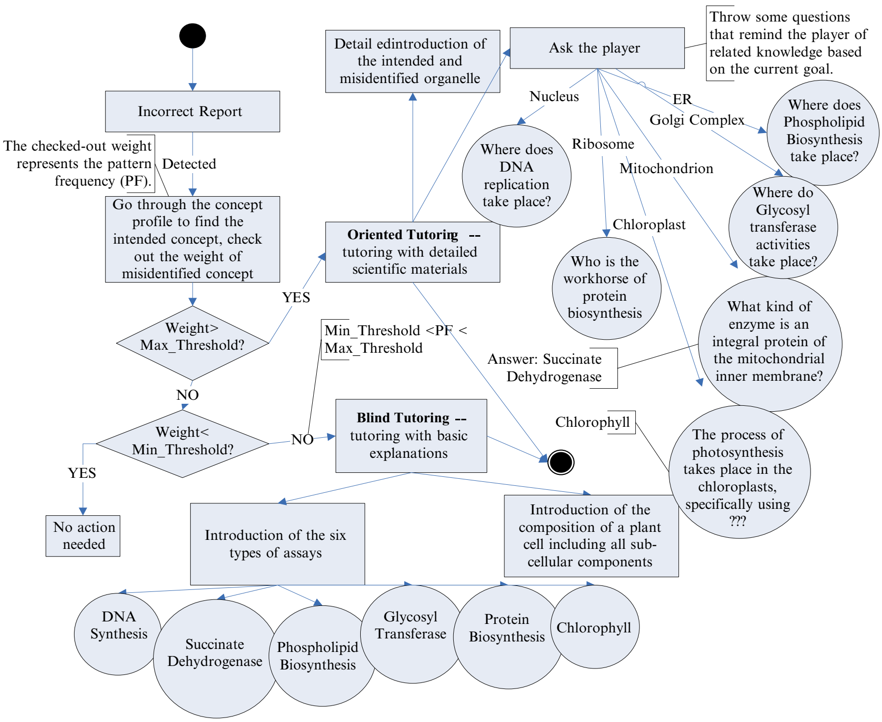

Fig. 20.8 The tutor's decision-making process for incorrect reports

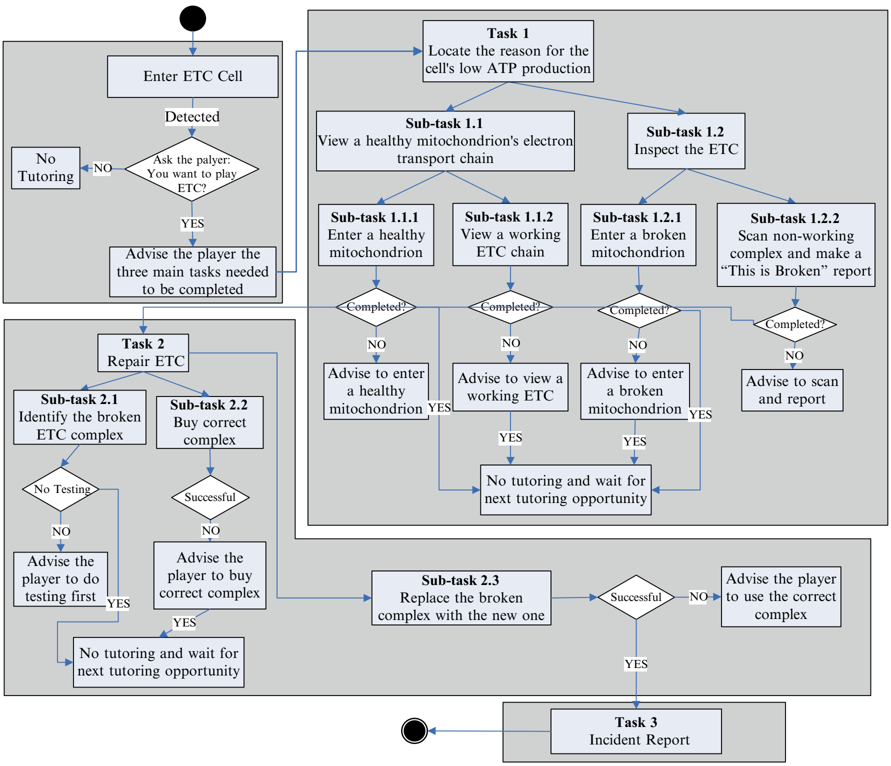

Fig. 20.9 Tasks and tutoring opportunities in the ETC module

3.3 ETC and Photosynthesis Tutors

We adopt similar tutoring strategies in the ETC and Photosynthesis modules since they have similar goal structures. The ETC occurs in mitochondria as the third and last stage of cellular respiration. Tutoring strategies for the ETC are illustrated in Fig. 20.9. Tutoring is offered if a failed task completion is detected. For example, "sub-task 2.2" requires the player to buy a complex. If the player fails to buy the correct one (e.g., an incorrect one is bought), a tutoring message will be sent to the learner.

However, appropriate tutoring opportunities might be difficult to recognize in some complex cases. For example, in the ETC module, the final task is to enable a broken mitochondrion to start transporting electrons. In order to activate the chain, broken carrier substrates that hold electrons like NADH dehydrogenase must be replaced. Before that replacement, a sequence of activities needs to be conducted: (1) check the current inventory to find a healthy complex; (2) buy a healthy complex if the current one is running out; (3) replace the broken complex with the healthy one. In this case, it is not certain all of the activities must be involved, which means one or more of them might not be needed based on practical considerations such as the current inventory status.

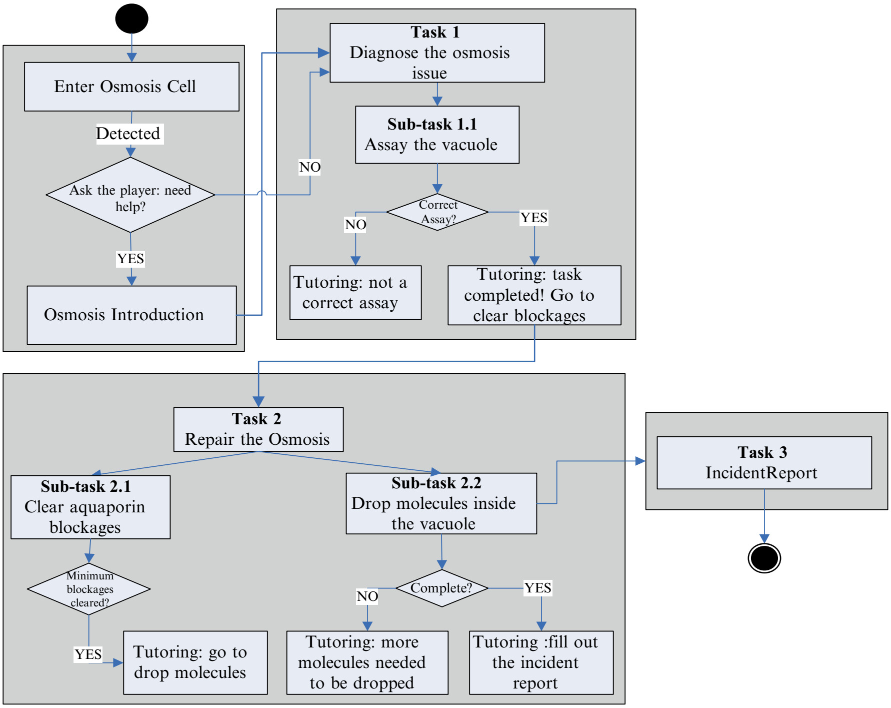

Fig. 20.10 Tasks and tutoring opportunities in the Osmosis module

Two alternative tutoring strategies are proposed to handle this issue. One is to wait until an incorrect substrate is chosen to replace the broken one, no matter whether the student inventory has the correct substrate or not. In this case, the student might get stuck if their inventory is running out of available substrates. The other is to check the student inventory before the replacement task is initiated.

3.4 Osmosis Tutors

The cell for teaching the osmosis process is designed to be dim and smaller than usual due to the lack of water flowing into it. All the organelles look broken. There are strange blobs studded along the walls. A tutor shows up to provide general instructions about the goals and tasks the first time a player enters this module. Tutoring opportunities are based on the tasks as illustrated in Fig. 20.10. Tutoring is offered if a task completion exception is detected. Such exceptions include: break the task dependencies, i.e. perform the tasks in incorrect order, stop in the middle of a task completion process. For example, “sub-task 2.2” requires the player to drop molecules inside the vacuole. If the player has dropped some, but not enough to reactivate the osmosis process, a tutoring message will be triggered.

Considering the students might get stuck by confusing the order of the given tasks or running out of substrates, in addition to that given in Fig. 20.10, the following tutoring opportunities have been identified:

- Tutoring for incorrect moves is offered if one of the following player actions is detected.
  - Start clearing plasmodesmata blockages before assaying the vacuole: a message is triggered to tell the player the precondition tasks have not been completed.
  - Continue clearing plasmodesmata blockages after the corresponding task has been completed: a message is triggered to tell the player they do not need to clear any more blockages.
  - Drop molecules outside the vacuole: a message is triggered to tell the player to go inside the vacuole to drop molecules.
  - Exit the vacuole without completing the "drop molecules" task: a message is triggered to tell the player the task has not been completed
- Tutoring for having detected the lack of substrates in the player's inventory.
  - After enough plasmodesmata blockages have been cleared, but the player's inventory has also run out of molecules, they will be given a message regarding this situation. The player is required to acquire molecules in order to complete the next task.

3.5 Tutoring with Mini-games

Three mini-games (the Electron Transport Chain mini-game, the Photosynthesis mini-game and the Osmosis mini-game) have been integrated into the Virtual Cell as an important tutoring resource in our knowledge base. These mini-games are meant to reinforce the basic concepts of a module and provide motivation to practice particular skills without necessarily using the same submarine-flying-around modality as the original lesson (Borchert et al., 2013).

Specifically, the Electron Transport Chain (ETC) mini-game (Fig. 20.11) is an orientation puzzle game, where the objective is to rebuild one or more ETCs by rotating and/or aligning complexes. Figure 20.11 shows the first level of the electron transport chain mini-game. Instructions are shown on how to play the game. When enough ETCs are functioning properly, ATP production will be steady enough to complete the level. The Photosynthesis mini-game (Fig. 20.12) focuses on the light reactions where the player places a set of puzzle elements on a grid to direct photons to the photosystem(s), or rotates a series of pipes to guide water from a source to the outlet which is located under the photosystem complex. Figure 20.12 shows level 7 of the photosynthesis mini-game. Movable elements on-screen include: a splitter to split light beams, a light polarizer to change the wavelength of the light to be appropriate for either the Photosystem I or Photosystem II complexes, and a mirror to reflect light.

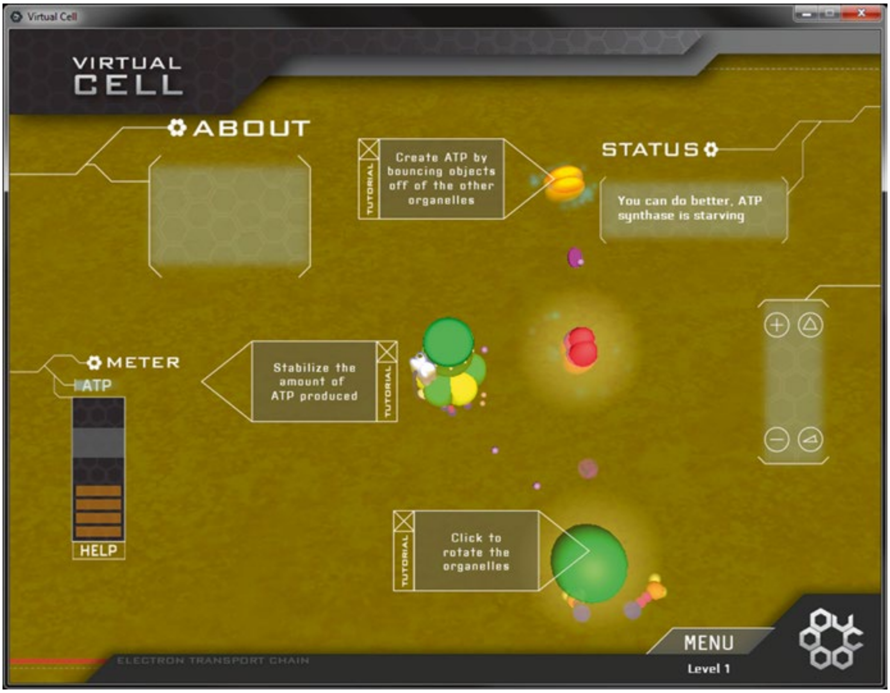

Fig. 20.11 The ETC mini-game

The Osmosis mini-game (Fig. 20.13) is a mathematical puzzle where the player is required to repair a broken osmosis process by calculating the amount of water molecules needed to be placed inside and outside the plant cell. The culminating objective is to teach the solute-concentration concept which is consistent with the goal of the Osmosis module. Figure 20.13 shows the first level of the osmosis mini-game. Instructions are shown on how to play the game.

The player may actively navigate to the mini-games by talking to the tutor in each module, or inactively be advised to do so if the tutor detects that he/she is encountering a difficulty in accomplishing the current learning goal. For example, in the Photosynthesis module, one task is letting the player improve the cell health by repairing a broken chloroplast. If the player fails to complete this task several times, it implies that the player may not understand what substrates are needed for the photosynthesis. At this point, the Photosynthesis mini-game would provide an illustration of how photosynthesis works. Once this situation is detected, the tutor will come to the player, providing a pathway to guide the player to the Photosynthesis mini-game.

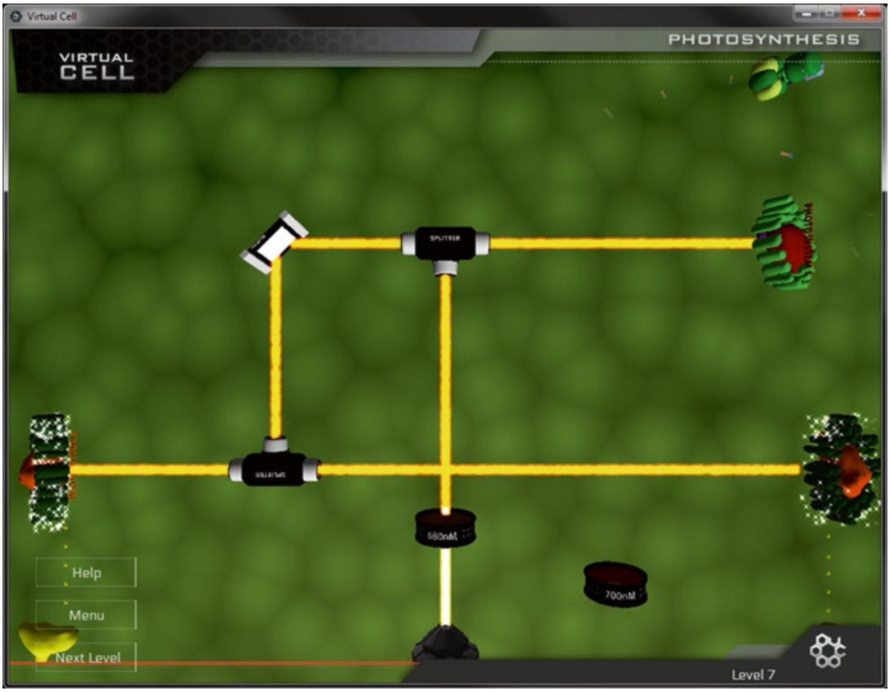

Fig. 20.12 The Photosynthesis mini-game

4 Simulation Verification

The WoWiWe Instruction Co. has collaborated with North Dakota State University to develop a software testing framework named Crushinator (Jacobs & Schaefer, 2012; Schaefer, 2013; Schaefer, Do, & Slator, 2013) to verify the correctness and performance of the Virtual Cell game server. The Crushinator provides a framework that tests event-driven, client–server based game applications and automates processes by incorporating multiple testing methods such as load and performance testing, Model-based Testing (MBT), and exploratory testing (Schaefer et al., 2013). Since the Osmosis module had not been completed by that time, a test was performed on only the first three modules (i.e. the ID module, the ETC module and the Photosynthesis module). The correctness test was based on the three goal systems of the three modules. Specifically, the Crushinator implemented two testing approaches: MBT and Model-Based Exploratory Testing (MBET). These test cases were then executed respectively for defect detection. As a result, 33 defects in an early development stage of the Virtual Cell game server were identified (Schaefer et al., 2013).

For load and performance testing, four separate test engines (a load test engine, an exploratory test engine, an HTTP test engine, and a standard socket test engine) were implemented in the Crushinator so that it was able to simulate multiple virtual clients connecting and communicating with the Virtual Cell game server (Schaefer et al.,

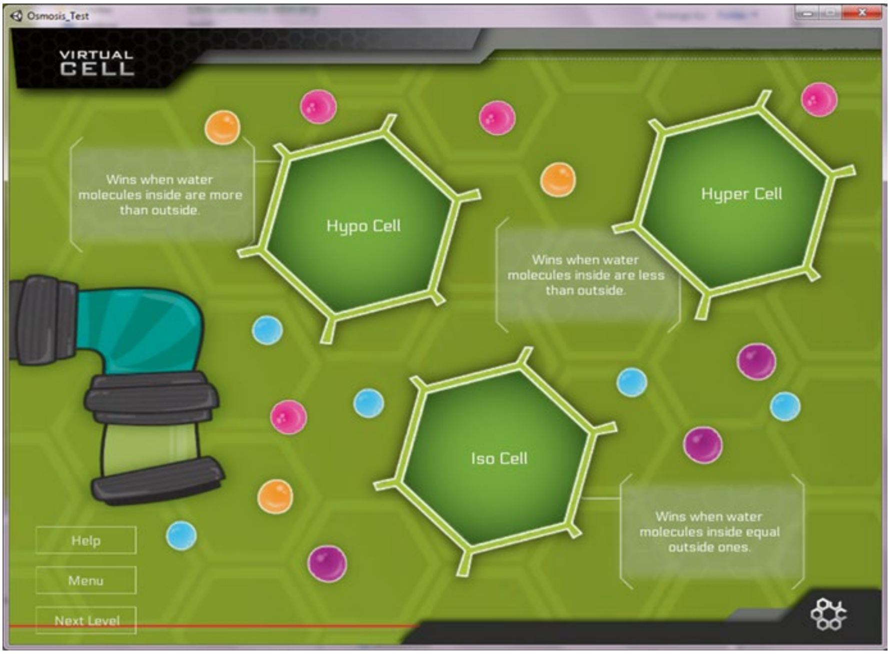

Fig. 20.13 The Osmosis mini-game

Table 20.2 Experiment specifications

Test ID	# of Players	# of Events	Duration (min)	Description
1	30	500	5	All players on all servers log in and send GetSceneState events
2	30	500	5	All players for one server log in, then all players for the next, etc. (a staggered log in) then all players send GetSceneState events
3	30	17,000	30	A staggered log in, then all players playback a pre-recorded play-through
4	40	500	5	A staggered log in, then GetSceneState events
5	40	17,000	30	A staggered log in, then all players playback a pre-recorded play-through

2013). Specifically, three collections of Virtual Cell game servers were instantiated on a single "Linode 2GB" instance. There were four, six, and eight servers in the collections respectively. Five experiments (Table 20.2) were run on each collection one after the other. After all tests were completed, the current collection of servers was destroyed, and the next collection was installed and brought online. For example, the experiment with "1" as the "Test ID" in Table 20.2 simulated the process of 30 players logging into the game server. It took 5 min and had 500 "GetSceneState" events sent to the server. The Crushinator recorded the series of events and responses that took place, and the response times for each player's event (the latency).

Table 20.3 System response times

# of Servers	Test ID	Latency (ms)
4	1	7000
	2	150
	3	80
	4	100
	5	100
6	1	1000
	2	150
	3	100
	4	–
	5	–
(6-1)	1	–
	2	–
	3	–
	4	350
	5	100
8	1	9000
	2	200
	3	–
	4	–
	5	–
(8-3)	1	–
	2	–
	3	100
	4	–
	5	100

The latency is detailed in Table 20.3, and the test results were analyzed by the development team and used as one of the more important metrics in tuning the performance of the system. The test results demonstrated that we could easily support 30 players each on 4 separate Virtual Cell servers (120 players). In Table 20.3, the first column indicates the number of servers in the collection ("8-3" denotes the 8 servers less the 3 that crashed); the second indicates which test was performed, i.e. the experiment ID; the third indicates the average latency, i.e. the server response time ("-"either denotes a failed test or no data available).

5 Discussion

This paper proposes a new solution to intelligent software agent tutoring that integrates data mining techniques with intelligent agents. This instructional system aims to individualize learning experiences through the incorporation of a data mining model based on student learning history. Blind tutoring is provided to meet the requirements of a majority of the students, while oriented tutoring is customized for struggling students. The integration of these data mining techniques for tutoring would be applicable in related areas such as educational psychology and student-centered learning. To support the development of such tutors, a comprehensive goal system that covers various pedagogical scenarios, targeted to focus the learning process on academic goals is presented. In this virtual environment, students demonstrate mastery of required knowledge and skills through the completion of these learning goals.

The solution introduced in this work is implemented in an educational 3D game for biology students, Virtual Cell (Vender et al., 2010; Borchert et al., 2013). Besides cellular biology, there is potential for adapting this solution to other applications that involve scientific reasoning and scientific methods. For example, the proposed data mining model can be re-used in other educational game areas: psychology, math, physics, social science and humanities. The goal system supports cellular biology education and is extendable to meet the needs of sub-disciplines such as bacteriology, neurology, and many other specialized processes in multicellular organisms.

For future work, the ontologies developed in this task can be further improved to fit more learning activities. Furthermore, more tutoring opportunities might be discovered by collecting and analyzing the logs generated from mini-games. Common patterns can be generalized to construct typical learning cases for library enrichment. We will be exploring these issues and evaluating their performance in our future work.

6 Conclusion

Visualization and simulation techniques show great potential in engaging and informing students in science education. Our primary mission in this effort is to develop experimentally validated educational experiences to parents, students, teachers, and members of the general public (Borchert et al., 2013). Our approach focuses on designing software tutors that are capable of identifying student learning obstacles in a timely and accurate manner, creating opportunities for immediate relevant feedback. This feedback plays an important role in improving educational efficacy. In addition, we offer other fundamental techniques for teachers and educational leaders to design and implement effective e-learning environments. These include the design of a structured and comprehensive goal system, the development of various tutoring strategies targeted to multiple pedagogical scenarios, and the implementation of a 3D Immersive Virtual Environment (IVE).

One of the motivations for creating a virtual role-playing environment for science education is to encourage and guide students to transfer their engagement in game playing to the understanding of real-world concepts and procedures. Game-based learning associated with intelligent software tutors encourages students to learn diagnostic problem-solving skills in a learn-by-doing environment. Effective use of these novel instructional technologies allows teachers to better understand and ultimately improve student learning behaviors.

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Chapter 21
A Synthesizing Look Forward in Teaching, Learning, and Educational Leadership in the Digital Age

J. Michael Spector, Dirk Ifenthaler, Demetrios G. Sampson, and Pedro Isaías

Abstract It is reasonable to ask whether and to what extent digital technologies have had an impact on teaching, learning, and educational leadership. The CELDA (Cognition and Exploratory Learning in the Digital Age) conferences have been exploring that question for the last dozen years. Looking back, one finds most papers aimed at the lesson and course level and focused on learners. The same is generally true of related conferences such as the International Conference on Advanced Learning Technology (ICALT) and the annual conference of the Association of Educational Communications and Technology (AECT). What has happened in recent years is the inclusion of research and development focused on teachers and educational systems as well as continuing emphasis on efforts investigating how to design and implement technology enhanced support for learners in a wide variety of contexts. This chapter offers a conceptual framework for research and development at multiple levels in support of improved teaching, learning, and educational systems. Specific emphasis is given to the articulation of needs and findings among and between various groups, including students, teachers, administrators, parents, and

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policy-makers. The basic argument is that too little articulation has occurred between and among the key groups involved in education, and that deficiency has resulted in a generally low level of sustained and systemic impact on education involving new technologies and innovative instructional approaches.

Keywords Advanced learning technologies • Educational systems • Exploratory learning • Instructional design • Research into practice • Research into policy-making

1 Introduction

Educational research has established a number of significant findings over the years with that account for most of the variance in terms of individual learning outcomes that generalize across populations and contexts, including: (a) prior knowledge and experience, (b) timely and informative feedback, and (c) time-on-task (see, for example, Huitt, Huitt, Monetti, & Hummel, 2009; Pazzani, 1991; Shute, 2007; Spector & Anderson, 2000; Spector, 2015). From a pedagogical and instructional design perspective, knowing a learner's prior knowledge and experience along with a current understanding of progress and performance can provide the basis for providing timely and informative feedback as well as generating meaningful activities that can result in increased time on relevant learning tasks, thereby increasing understanding and learning. That general line of reasoning flows from the things to be learned to knowledge about individual learners to providing effective support to improved learning. The logic seems quite compelling: If an instructor understands what is to be learned and knows enough about a particular learner, then that instructor can provide encouraging, meaningful and support feedback, and create activities that are likely to be engaging for that individual and result in more quality time on a relevant learning task and improved learning outcomes (see Fig. 21.1).

Figure 21.1 depicts the role of prior knowledge, formative feedback and time-on-task as they affect learning and performance. In addition, the role of technology in providing support for innovative pedagogical approaches and highly engaging learning activities is depicted. This diagram also depicts the possibility of personalized learning environments, which the New Media Consortium's 2015 Horizon Report: Higher Education Edition indicates is a difficult, elusive, and not yet realized challenge (see http://cdn.nmc.org/media/2015-nmc-horizon-report-HE-EN.pdf).

Examples of the logical flow described above can be found in some of the most innovative and inspiring efforts in the last 50 years. An early example of this general approach is the Jasper Woodbury project created by the Cognition and Technology Group at Vanderbilt University (CTGV, 1990). That project was built on the notions of anchored instruction and situated cognition, which fit within the scheme indicated in Fig. 21.1 by emphasizing student interests and engagement, authentic tasks, exploration, and formative feedback (see http://www.edu-design-principles.org/dp/viewFeatureDetail.php?feKey=516).

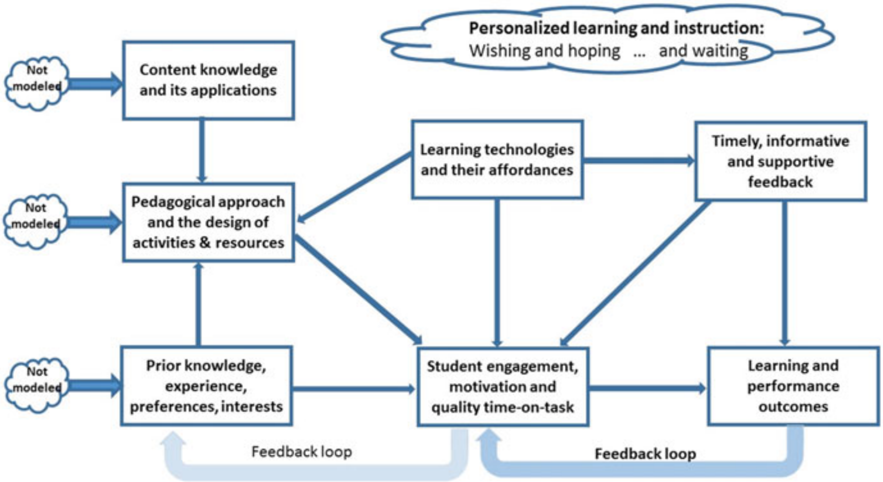

Fig. 21.1 A logical flow for improving learning

One of the results of projects such as Jasper Woodbury is the expansion of teaching competencies from pedagogy and content knowledge to include technology affordances and integration—from PCK (pedagogical content knowledge) to TPACK (technological, pedagogical, and content knowledge) (Mishra & Koehler, 2006; Shulman, 1986). The CELDA meetings have historically been organized around the concept of effective technology integration into innovative learning and performance environments found in the Jasper Woodbury projects and other more recent exemplars (e.g., WISE—Web-based Inquiry Science Environment—https://wise.berkeley.edu/; Knowledge Forum—http://www.knowledgeforum.com/). Most of the research reported at prior CELDA meetings has focused on specific technology-enhanced learning interventions for various subjects in a limited number of classrooms. Some of this research will be reviewed briefly in the next section. The CELDA 2014 meeting marked an explicit recognition that preparing technology informed teachers and supporting innovations by teachers in schools was an important step forward in the process of fostering the diffusion of innovation. The CELDA 2015 meeting continues the emphasis on educational technology leadership with the hope that CELDA conferences and associated research will begin to have a large-scale and systemic impact on learning and instruction.

2 Educational Research

A paper by Darabi, Nelson, and Seel (2008) presented at the 2008 CELDA conference in Freiburg, Germany, and published in the edited volume associated with that conference investigated the role of formative feedback in the development of mental models. The general notion informing the study is that the progressive development of relevant and productive mental models is a vital step in helping a student acquire competence and develop a deep understanding of complex problems and situations (Seel, 2003). The context involved was an undergraduate engineering course, and the focus was on developing an understanding of feedback mechanisms in a chemical plant's operations. The intervention involved a simulation of the chemical plant's operator's panel complete with instrument readings and operator controls. All the participants received the same supportive formative feedback, based in part on how experts reacted to problems programmed into the simulation. Overall, learners developed a deeper understanding of the plant's operations and began to make expert-like decisions. However, those who had initially tested low in terms of cognitive flexibility, mental effort and number of errors benefitted more from the formative feedback than did the high performing group. The researchers suggested that time-on-task, which was the same for all, may not mean much unless there is meaningful, timely, and informative feedback accompanying the effort. The feedback was apparently less meaningful for the high performing group so the time-on-task was less impactful on their progressive development.

A second study by Hadjerrouit (2013) presented at the CELDA 2011 conference in Rio de Janeiro, Brazil, investigated collaborative writing with wikis. The general notion motivating this study was the potential role of collaboration in supporting complex learning activities in an online learning environment (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989). The study involved graduate students enrolled in Web 2.0 technology courses, some of whom were teachers but none with prior experience in collaborative writing. Academic writing is acknowledged as a complex task, and those who are new to publishing an academic paper find that task especially challenging. The learning task was to develop a group-authored paper using a wiki to support the effort. The general hypothesis was that online collaboration through a wiki would benefit all and result in well-developed papers. The finding included minor problems with the technology, which can be overcome in subsequent implementations, but lower-than expected levels of collaboration. This was partly explained by a tendency for one or two students to dominate a collaborative activity and by lack of familiarity with regard to collaborative writing and the potential benefits that could accrue. A recommendation for future studies was to include at least one face-to-face meeting for each group and to provide more support for genuine collaboration (e.g., by requiring the group first to negotiate in selecting the topic and scope of the paper). In addition, those teachers who are integrating collaborative writing need to provide more explicit support initially about the potential benefits and closely monitor progress of each collaborative effort. This study again demonstrates that time-on-task alone is not sufficient to support learning—timely, meaningful, and informative feedback during learning activities is vital.

A third study by Yoon, Wang, and Elinich (2014) presented at CELDA 2012 in Madrid, Spain, investigated augmented reality in science museums. The general notion informing this study was the notion that informal learning can benefit formal learning; more specifically, getting museum visitors to spend more time with a specific museum exhibit would result in improved understanding of that exhibit and potentially contribute improved learning (Screven, 1993). The technology involved in this series of studies was augmented reality, and the focus was on interactive exhibits involving science (see the Ariel Project at https://www.fi.edu/augmented-reality). The exhibits were aimed at middle school students visiting the museum to supplement their formal learning about various science topics. The exhibits include knowledge building scaffolds (i.e., formative feedback built into the informal learning science exhibits). Support for social networking and collaboration was also included in the exhibits. The findings include the fact that the interactive exhibits were engaging and that visiting students did spend significant time with those exhibits. Subsequent test scores in science suggest modest gains in learning. The researchers noted some tension between formal and informal learning situations, but the indications are that properly supported informal learning exhibits that have engaging interfaces and include formative feedback can promote science education. The Draper Spark!Lab in the West Wing of the Smithsonian National Museum of American History is a recent example of a related effort on a larger scale (see http://americanhistory.si.edu/exhibitions/sparklab).

What these and other research projects demonstrate is that combining timely, informative feedback with engaging activities that result in more quality time on a learning task can promote learning. It is worth noting that like most responsible scientists, these researchers recommend further replication studies to develop increased confidence in the findings. A report by Baker (2015) attempting to replicate 100 research findings in psychology found that only 39 of the published studies could be replicated. While it is good to recommend replication, it is important to provide sufficient details about instrumentation and protocols to support a replication study by other researchers.

While the most recent example has an analogous effort in a national museum, the impact of these and other research projects involving advanced digital technologies in support of exploratory and inquiry learning have had only minimal impact on a large scale and have yet to transform educational systems in productive ways. Future CELDA meetings will continue to explore the reasons for the lack of significant and sustained impact of innovative and promising technologies on a large scale. In the next section, a few preliminary remarks about the nature of educational systems and the challenges involving in changing them are discussed.

3 Educational Systems

It is possible to categorize typical educational goals in terms of developing (a) basic knowledge and skills, (b) productive workers, (c) effective problem solvers, (d) analytical and critical thinkers, (e) responsible citizens, and (f) lifelong learners (Spector, 2015). Various institutions and educational systems supporting students at different levels place emphasis on some of these categories and largely ignore others. For example, primary education is often aimed at (a) and perhaps (e) in the previous list. Secondary education schools and programs typically emphasize (a) and (c). Technical and vocational schools obviously emphasize (b). Higher education typically emphasizes (c) and (d). A careful reading of Dewey's (1938) *Experience and Education* suggests that all of these need to be emphasized but that traditional education (in America in the first part of the twentieth century) have only emphasized the first three (a, b, and c).

Others have noticed a similar tension between traditional and progressive learning since Dewey brought this tension to the national stage in America in 1938. School reform initiatives have since arisen in many countries in an effort to emphasize aspects of (d), (e), and (f). For example, in 1961, the Academy for Educational Development was founded to promote more progressive approaches to learning and in 2011 joined with the Family Health International to achieve a more global impact (see http://www.fhi360.org/). Enders, de Boer, and Westerheijden (2011) report that educational reform in Europe is happening with many promising efforts at various levels. However, that volume also notes that much more can and should happen, and that efforts to date have resulted only in sporadic and marginal changes in classrooms. In South Korea, educational reform has been dramatic when measures such as the PISA (Programme for International Student Assessment; see http://www.oecd.org/pisa/) studies are used. However, a closer look at the educational system in South Korea shows that changes in the system there were largely influenced by the Learning Systems Institute at Florida Institute which helped establish the Korea Educational Development Institute and the Korean Educational Research Institute. There is a promising new primary school that has been implemented; however, that does represent a genuine school reform project from the ground up (Rieh, Kim, & Yu, 2011). That effort involves environmental friendly building design, open classrooms, spaces to encourage collaboration, multi-grade activities, and much more. That effort needs to become a model for progressive development emphasizing all of the educational goals mentioned previously.

The question that must be asked and addressed, however, is why has there been so little change when there have been so many remarkable projects demonstrating the potential for new approaches and new technologies. One partial response has to do with the way that teachers are trained in preservice teacher preparation programs and how they are involved (or not) in innovative research efforts in their schools. Teacher training has changed very little in many (or most) university programs. Teachers are being trained for twentieth century schools using nineteenth century technologies (e.g., using a word processor as if were a typewriter or using a smartboard like a chalkboard). In higher education, there is a tendency to teach as one was taught, especially by a favorite professor.

In addition, in universities, there is a great deal of consolidation around traditional disciplines and faculties, with ever more resources available. That tendency tends to inhibit innovative interdisciplinary efforts and creates what many have called silos of learning and instruction. This was evident at a recent meeting of the National Technology Leadership Coalition (NTLC; see http://ntlcoalition.org/) in Washington, D.C. involving the next-generation science standards that strongly and activity encourage the integration of engineering into science education (http://www.nextgenscience.org/next-generation-science-standards). While those standards are generally forward looking, interdisciplinary and supportive of authentic learning activities, at the NTLC meeting, it was the science educators who expressed reluctance at having technology and engineering divert student interest from the basic concepts and principles of science that they value so highly. One of the authors of this chapter refers to this as the *Moses effect*—one has to wander around in the desert for 40 years waiting for the old generation to die off if one really expects change.

There are other barriers to productive, transformative change of educational systems. Some involve policies established by nations, states, and school districts which are notoriously slow to embrace change. Another barrier involves funding for new initiatives. While there is a great deal of discourse around the world in support of education, when one examines the comparative levels of funding for education, economic development, defense, and noneducational social programs, it becomes evident that there is more talk than action with regard to financial support for education (for example, see http://www.cbpp.org/research/most-states-funding-schools-less-than-before-the-recession for funding in the USA; for educational expenditure statistics in Europe, see http://ec.europa.eu/eurostat/statistics-explained/index.php/Educational_expenditure_statistics).

There are other barriers to systemic educational reform, such as cultural and religious resistance to some changes. However, a serious barrier to progressive change is the failure to understand a school or education more broadly as a system. This failure can account for the failure of researchers to see that their efforts have a system-wide impact as opposed to a school-wide impact (even a school-wide impact is a significant challenge). Viewing education as a system requires recognizing multiple stakeholders with a variety of perspectives (teachers, students, parents, administrators, policy-makers, industry, developers of educational technologies and tools, etc.) and with noncongruent goals (improve learning, improve graduate rates, improve corporate competiveness, improve sales, etc.). Moreover, understanding that the lessons learned from prior research require further study and seem to work in combination and concert with each other rather than in isolation requires a sophisticated understanding of that body of research. That is to say that focusing on time-on-task alone is not likely to have much of an impact if time, formative and meaningful feedback is ignored. Designing and implementing a highly interactive interface for science exploration might well fail if it cannot flexibly support a variety of different student interests.

A final remark about educational systems is to encourage a view of the interactions between basic research, applied research, educational practice, and educational policy-making as multidimensional and multidirectional. Practice should also inform research just as research should inform practice. Policy-making should not be solely a top-down activity controlled by a few; policy-making should embrace all those with a stake in improving learning and instruction, and that includes students and parents, who are nearly always left out of the decision-making loop, with teachers having only marginal input.

4 Conclusion

The conclusion of this chapter should by now be obvious. Whereas there have been many innovative and promising efforts in the area of new approaches and new technologies to support learning and instruction, including those reported in this volume, as a community of educational professionals can do better. We must do better. We must replicate studies to develop confidence in findings. We must put promising research into practice on a larger scale. We must see that policy-makers hear about promising efforts.

What has been happening all too often is that a remarkable effort may makes its way into the public eye but little changes in spite of widespread notice of a remarkable achievement (see, for example, the Underwater Dreams effort from Carl Hayden High School in Arizona at https://www.youtube.com/watch?v=2FqCO5clKR0). That effort involved an after-school project building underwater robots in a high school serving a minority population over a period of about 10 years showed how much could be learned by students who had been told they could never complete college or achieve anything of significance. Has the effort resulted in any systemic changes in education in Arizona or in any changes about minority students? None have been reported and the general population of Arizona remains firmly opposed to changing immigration policies.

Surely it is the best of times with regard to the potential of new technologies to have a significant and sustained impact on learning and instruction. It is the worst of times when one considers how little has actually been accomplished in terms of large-scale, systemic change in transforming education for the benefit of all and not just the privileged few. We can do better.

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