ASCILITE
SHAPING THE FUTURE OF TERTIARY EDUCATION
Show Me The Learning
Adelaide, Nov 27-30, 2016

Designing and Analysing STEM Studios for preservice teacher education

Kate Thompson
School of Education and Professional Studies
Griffith University

Harry Kanasa
School of Education and Professional Studies
Griffith University

There is a need for approaches to understand the teaching and learning of STEM and STEAM in schools in order to prepare preservice teachers for innovative classroom practice. In this paper we use a combined design approach to examine the activity of school students, preservice teachers and graduate STEAM students in two STEM Studios at a University in Queensland. We present our revised conceptual model based on earlier iterations as part of an OLT funded project. Multimodal learning analytics approaches will be applied in order to understand the integration of knowledge processes, epistemic cognition, collaboration and tool use.

Keywords: STEM Studio, preservice teacher education, learning analytics, design based research

Introduction

STEM Studios or makerspaces provide interested students and community members with space, resources and expertise to create technology-based solutions. In STEM Studios, coding and programming are authentically linked to robotics, electronics, and more complex creative work. In parallel with, and to support, the integration of the Australian Curriculum in Technologies (ACARA, 2016), makerspaces have the potential to support interdisciplinary, creative, collaborative problem solving for school students and teachers. In order to prepare primary and secondary preservice teachers for this challenge, we need to understand STEM Studios as complex learning environments, where multiple knowledge building processes, social interactions and specialist tool use need to interact in order to complete an open-ended, evolving task. We invited school students from local schools to work on projects for a STEM competition at two STEM Studios located on Queensland University campuses, outside normal school hours, one afternoon a week, for eight weeks. In order to understand the relationship between design, learner activity, and learning outcomes, we are taking a combined design approach (Thompson, Gouvea & Habron, 2016). This combined design approach draws on Sandoval's (2014) conjecture mapping to guide the design based research, and Carvalho & Goodyear's (2014) activity centred analysis and design (ACAD) framework to guide the analysis of the design in relation to activity and learning outcomes. In the context discussed in this paper, learners include *school students* (using a STEM Studio as an after school club), *preservice teachers* (volunteering at the STEM Studio), as well as *graduate students* (volunteering from science, engineering and the arts).

Multiple sources of data including video, audio, screen capture, as well as physical artefacts, and questionnaires and interviews (Thompson, Ashe, Carvalho, Goodyear, Kelly & Parisio, 2013) will be collected. Data will be extracted to examine gaze (e.g. Worsley & Blikstein, 2015), movement (e.g. Raca & Dillenbourg, 2014; Raca, Tormey & Dillenbourg, 2013), discourse (e.g. Thompson, 2013), and artefact creation (e.g. Oviatt & Cohen, 2014) in order to understand the integration of knowledge processes, epistemic cognition, collaboration, and tool use. The ultimate aim of the research is to understand a) the complex nature of school students' learning in such spaces; b) implications for preservice teacher practice; c) scientists' appreciation of communication of STEAM practices and concepts; and d) to refine the STEM studio model for its inclusion as a formal course for preservice education students. In this paper, we present our initial conceptual model of the project, based on research from previous iterations of the STEM Studio project.

The STEM Studio approach builds on recent research (Brandt, Cennamo, Douglas, Vernon, McGrath & Reimer, 2013; Gershenfeld, 2005; Blikstein, 2013) as well as ongoing work by members of the project team as part of the OLT funded STEP-UP project (www.stepup.edu.au). Makerspaces (Rosenfeld Halverson, & Sheridan, 2014), FabLabs (Gershenfeld, 2005; Blikstein, 2013), and STEM Studios (Brandt et al., 2013) are informal spaces, for community members, or after-school clubs (Evans, Lopez, Maddox, Drape, & Duke, 2014), that provide opportunities for students to learn through the creation of innovative solutions. It is an effective learning environment in informal (e.g. Brandt et al., 2013; Evans et al., 2014), and formal contexts (e.g., Blikstein, 2013;

Loristen Girls School, 2016), however the role of the teacher and the complex nature of the learning in these contexts have not been investigated.

In this STEM Studio approach, we encourage preservice teachers to consider an interdisciplinary approach to problem solving (Pennington, 2016). This interdisciplinary approach to teaching encourages a wide variety of knowledge and skills drawn from the Sciences (technology, maths, engineering) and the Arts (literacies, design, humanities) (Brady, 2014; Wintermann & Malacinski, 2015). We need to understand how teachers negotiate these relationships, and how they, and their students, can best be supported in the STEM Studio and outside it. The potential of STEM Studios lies in the intersection of the pedagogical approach, access to resources, and the collaborative nature of the learning. In order to solve a problem, students must integrate the specialised methods of multiple disciplines, negotiate social interactions, and apply this to creative work using new tools. If teachers are to scaffold students through these complex real world dilemmas, we need to understand what productive work in STEM Studios looks like.

Previous iterations of this STEM Studio approach focused on the role of self-efficacy in the practice of preservice teachers. Bandura (1977) defines self-efficacy as one's belief in their own ability to achieve a task. Based on work within social cognitive theory (Bandura, 1997) it acknowledges an interactive dynamic between beliefs, attitudes and opinions (our cognition) and our performance on a task (our behaviour). Whilst the impact of students' self-efficacy has been shown to be predictive of study behaviour (Zimmerman, Bandura & Martinez-Pons, 1992) as well as academic outcomes (Multon, Brown & Lent, 1991), a focus on teacher self-efficacy in the literature has been a more recent phenomenon (e.g., Fives, Hamman & Olivarez, 2007; Martin, Sass & Schmitt, 2012; Wheatley, 2005). Measurements of teacher self-efficacy are also suitable for the current study of pre-service teachers as direct measurements of the ability to teach in authentic contexts cannot be observed and previous studies (Albion, 1999) have shown self-efficacy ratings are a reliable predictor of future performance. The Norwegian Teacher self-efficacy scale (Skaalvik & Skaalvik, 2010) was chosen as the validated instrument to measure pre-services teacher self-efficacy pre- and post-intervention.

Methods

In this iteration of the STEM Studio approach, there are two informal learning environments, each on one of two university campuses at a Queensland University. School students can work on STEAM (Science, Technology, Engineering, Arts and Mathematics) projects outside normal school hours with the help of preservice teacher education students, graduate science and arts students, and researchers. Our research focuses on (1) *school students*, aged between 12-16 years, who wish to enter projects into a STEM competition; (2) *preservice teacher* volunteers; and (3) STEAM *graduate student* volunteers.

Multiple sources of data (video, audio, screen capture, as well as physical artefacts, and questionnaires and interviews) will be collected to examine gaze, movement, discourse, and artefact creation (e.g., coding, drawing). We aim to use these analyses to understand the integration of knowledge processes, epistemic cognition, collaboration, and tool use. This work will build on research in the application of automated and semi-automated methods to understand learner and instructor activity in complex learning environments (e.g. Martinez-Maldonado, Goodyear, Kay, Thompson & Carvalho, 2016; Thompson, Ashe, Carvalho, Goodyear, Kelly & Parisio, 2013; Raca & Dillenbourg, 2013; Worsley & Blikstein, 2015). In multimodal learning analytics (Blikstein, 2013), multiple modes of activity are considered, and a more systemic view of a learning situation is adopted as the results of the analyses are recombined in order to develop a model of understanding (Thompson, 2013). This research aims to be *actionable*, developed in combination with practitioners, with the aim of being able to use it to make decisions (Beardsley, 2011).

Results and Discussion

The STEM Studio project was first conducted in 2015 as one of three approaches under an OLT funded project to improve STEM Teacher Education. In the first iteration, training was provided in inquiry approaches, and in the tools used for communication between participants outside of face-to-face meetings. This first iteration focused only on preservice teachers, and relied on measuring changes in teaching self-efficacy. A comparison of preservice teacher teaching self-efficacy using the Norwegian Teacher Self Efficacy scale (Skaalvik & Skaalvik, 2010), pre- and post-intervention showed significant differences in three scales: (1) perceived ability to adapt instruction to individual needs; (2) maintain discipline; and (3) cope with change, all with medium effect sizes (Cohen, 1988). Researcher observations from the other STEM Studio approaches indicated that the inclusion of graduate students and other academics as STEM experts was successful. Based on these findings, as well as the need to better understand the activity of learners and preservice teachers that occurred during the STEM Studio sessions, the design of the research was modified for the 2016 iteration of the project.

We present the new design using the combined design approach (Thompson, Gouvea & Habron, 2016) in Figure 1 below. There are four key changes to the design of the research. First, we expanded our definition of "learners" beyond preservice teachers to include the graduate students, and school students. Broadening this definition means that design elements now include training for preservice teachers and graduate students in all inquiry approaches, as well as in the tools for collaboration. Second, we consider constructionism (Papert, 1980) and elements of interdisciplinary problem solving (Pennington et al., 2016) to be core to the processes of knowledge construction. Third, we expanded the physical and digital learning environment to include tools for technology and engineering (more commonly aligned with 'makerspaces' (Rosenfeld-Halverson & Sheridan, 2014)). Finally, we expanded our analysis to include the activity of all learners.

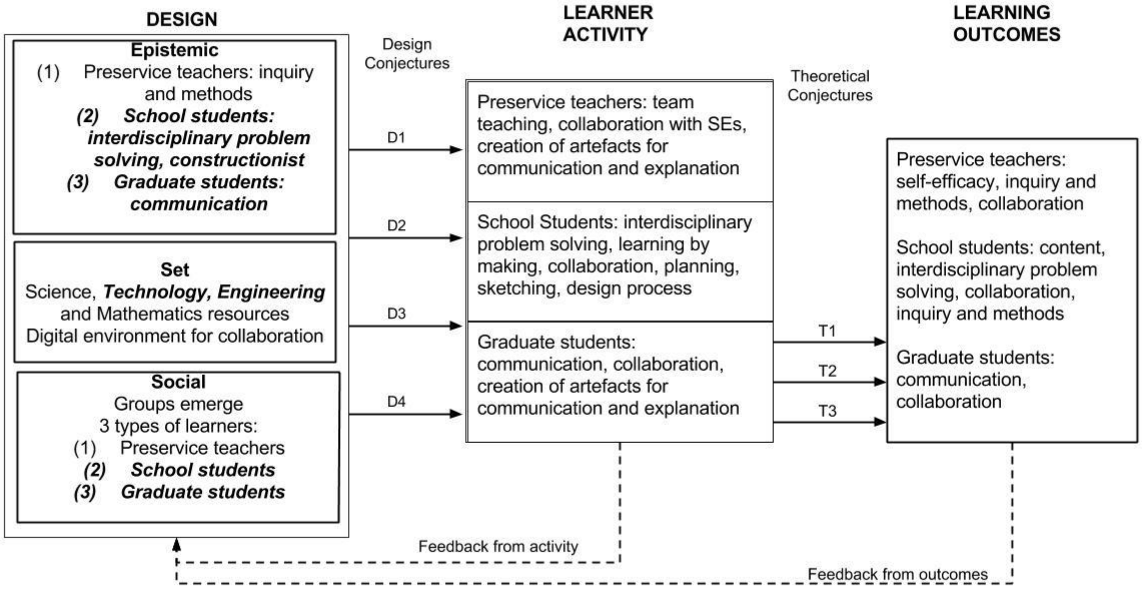

Figure 1: Iteration 2 of STEAM Room

In Figure 1, design (D1-D4) and theoretical (T1-T3) conjectures are identified relating to the role of school students, preservice teachers, and graduate students. The design conjectures are that:

> (D1) Graduate students will collaborate with other learners to help identify appropriate methods of inquiry;
> (D2) Preservice teachers will collaborate with graduate students to help communicate concepts and methods of inquiry to school students;
> (D3) The expanded physical environment will provide opportunities for new ways of explaining; and
> (D4) The interdisciplinary approach will facilitate collaboration between learners.

The theoretical conjectures are that:

> (T1) Training and its application will improve self-efficacy for preservice teachers;
> (T2) The interdisciplinary approach will improve preservice teachers' collaboration skills; and
> (T3) Graduate students' mentoring skills, communication skills, and collaboration skills will improve.

We also expect to be able to describe the interactions between school students, preservice teachers, and graduate students using the multimodal learning analytics described earlier. Previous work has focused on the analysis of discourse to identify patterns of idea generation (Thompson, Ashe, Yeoman & Parisio, 2013), and problem solving (Thompson, 2013). We aim to add to this by examining the role of the creation of mediating artefacts in the creation of STEM solutions. We also aim to investigate STEM and STEAM as a process of interdisciplinary problem solving, and the role of the integration of different perspectives in the creation of solutions.

Conclusions

There is a need for approaches to understand and design for the teaching of STEM and STEAM in schools in authentic and integrated ways. Investigating the detail of how a studio approach to learning and teaching STEM in an informal context has the potential to give us insights into how and what to integrate into classroom practice. By using the combined design approach, we aim to conduct ongoing, design-based research into the relationships between design, learner activity and learning outcomes. In addition, the use of multimodal learning analytics techniques will build on work that aims to apply a synthetic, systems approach to understanding complex learning environments. This will have implications for the opportunities for learning that we provide for our preservice teachers, to best equip them for innovative classroom practice.

References

ACARA (2016). Technologies Curriculum, F-10. http://www.australiancurriculum.edu.au/technologies/introduction, accessed 8th August, 2016.

Albion, P. (1999). Self-efficacy beliefs as an indicator of teachers' preparedness for teaching with technology. Presented at, the 10th International Conference of the Society of Information Technology and Teacher Education, 28 February - 4 March, 1999, San Antonio, TX, USA.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, 84, 191-215. https://doi.org/10.1037/0033-295X.84.2.191

Beardsley, T. M. (2011). Pulling at a tangled web. *BioScience,* 61(11), p. 843.

Blikstein, P. (2013). Digital Fabrication and 'Making' in Education: The Democratization of Invention. In J. Walter-Herrmann & C. Büching (Eds.), *FabLabs: Of Machines, Makers and Inventors.* Bielefeld: Transcript Publishers.

Blikstein, P. (2013). Multimodal Learning Analytics. *LAK 2013*, pp. 102-106.

Brady, J. (2014) STEM is incredibly valuable, but if we want the best innovators then we must teach the arts. *Innovation,* 5, pp. 1-5.

Brandt, C. B., Cennamo, K., Douglas, S., Vernon, M., McGrath, M. & Reimer, Y. (2013). A theoretical framework for the studio as a learning environment. *International Journal of Technology Design Education,* 23, pp. 329-348. https://doi.org/10.1007/s10798-011-9181-5

Brouwers, A., & Tomic, W. (2000). A longitudinal study of teacher burnout and perceived self-efficacy in classroom management. *Teaching and Teacher Education*, 16(2), 239-253.

Carvalho, L., & Goodyear, P. (2014). *The architecture of productive learning networks.* New York, NY: Routledge. https://doi.org/10.4324/9780203591093

Cohen, J. W. (1988). *Statistical Power Analysis for the Behavioural Sciences (2nd Ed)*, Hilldale, NJ: Lawrence Erlaum Associates.

Evans, M. A., Lopez, M., Maddox, D., Drape, T., & Duke, R. (2014). Interest-driven learning among middle school youth in an out-of-school STEM Studio. *Journal of Science Education and Technology,* 23, pp. 624-640. https://doi.org/10.1007/s10956-014-9490-z

Fives, J., Hamman, D., & Olivarez, A. (2007). Does burnout begin with student-teaching? Analysing efficacy, burnout, and support during the student-teaching semester. Teaching and Teacher Education, 23, 916-934. https://doi.org/10.1016/j.tate.2006.03.013

Gershenfeld, N. (2005). *Fab: The coming revolution on your desktop—From personal computers to personal fabrication.* New York: Basic Books.

Lauriston Girls School (2016). *The pioneer of the FabLab@School program is coming to Lauriston.* https://www.lauriston.vic.edu.au/about/lauristons-fablab-school (accessed 25/05/2016).

Martin, N. K., Sass, D. A., Schmitt, T. A. (2012). Teacher efficacy in student engagement, instructional management, student stressors, and burnout: A theoretical model using in-class variables to predict teachers' intent-to-leave. Teaching and Teacher Education, 28, 546-559.

Martinez-Maldonado, R., Goodyear, P., Kay, J., Carvalho, L. & Thompson, K. (2016). An Actionable Approach to Understand Group Experience in Complex, Multi-surface Spaces. *CHI'16*, May 07-12, 2016, San Jose, CA, USA. https://doi.org/10.1145/2858036.2858213

Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. Journal of Counselling Psychology, 38(1), 30-38.

Oviatt, S. & Cohen, A. (2014). Written activity, representations and fluency as predictors of domain expertise in mathematics. *Proceedings of the 16th International Conference on Multimodal Interaction,* pp. 10-17.

Pennington, D., Bammer, G., Danielson, A., Gosselin, D. C., Gouvea, J., Habron, G., Hawthorne, D., Parnell, R. A., Thompson, K., Vincent, S., & Wei, C. (2015) The EMBeRS project: Employing model-based reasoning in socio-environmental synthesis. *Journal of Environmental Studies and Sciences,* October

Raca, M. & Dillenbourg, P. (2014). Classroom social signal analysis, *Journal of Learning Analytics,* 1(3), 176-178. https://doi.org/10.18608/jla.2014.13.16

Raca, M., Tormey, R. & Dillenbourg, P. (2013). Student motion and its potential as a classroom performance metric. *3rd International Workshop on Teaching Analytics (IWTA).* Rosenfeld Halverson, E. & Sheridan, K. M. (2014). The maker movement in education. *Harvard Educational Review,* 84(4), pp. 495-504.

Sandoval WA (2014) Conjecture mapping: An approach to systematic educational design research. *Journal of the Learning Sciences*, *23*, 18–36. https://doi.org/10.1080/10508406.2013.778204

Skaalvik, E. M. & Skaalvik, S. (2010). Teacher self-efficacy and teacher burnout: A study of relations. *Teaching and Teacher Education,* 26, 1059-1069. https://doi.org/10.1016/j.tate.2009.11.001

Thompson, K. (2013). Using micro-patterns of speech to predict the correctness of answers to mathematics problems: An exercise in multimodal learning analytics. International Conference on Multimodal Interaction, ICMI 2013, New York City, New York: ACM Digital Library

Thompson, K., Ashe, D., Carvalho, L., Goodyear, P., Kelly, N., Parisio, M. (2013). Processing and Visualizing Data in Complex Learning Environments. American Behavioral Scientist, 57(10), 1401-1420.

Thompson, K., Ashe, D., Yeoman, P., & Parisio, M. (2013). Phases of design: Following idea development and patterns of collaborative discussion in a learning by design project. The 10th Int'l conference on Computer Supported Collaborative Learning, Madison, Wisconsin, pp. 494-501.

Thompson, K., Gouvea, J., & Habron, G. (2016). A design approach to understanding the activity of learners in interdisciplinary settings: Environment and Diversity. *To be presented at the International Conference of the Learning Sciences, June 19-24, Singapore, 2016.*

Wintermann, B. & Malacinski, G. (2015) Teaching evidence-based innovation as a transdisciplinary professional skill in an undergraduate biology writing workshop. *International Journal of the Arts and Science,* 8(2) p. 423.

Worsely, M. & Blikstein, P. (2015) Leveraging multimodal learning analytics to differentiate student learning strategies. *Proceedings of the Fifth international conference on learning analytics and knowledge,* pp. 360-367. https://doi.org/10.1145/2723576.2723624

Zimmerman, B. J., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. American Educational Research Journal, 29(3), 663-676.

Please cite as: Thompson, K. & Kanasa, H. (2016). Designing and Analysing STEM Studios for preservice teacher education. In S. Barker, S. Dawson, A. Pardo, & C. Colvin (Eds.), *Show Me The Learning*. *Proceedings ASCILITE 2016 Adelaide* (pp. 566-570). https://doi.org/10.14742/apubs.2016.835

Note: All published papers are refereed, having undergone a double-blind peer-review process.