Collaborating With Stakeholders in STEM Studios

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Abstract: Studio-based learning provides an environment in which a collaborative, problem-based approach to learning Science, Technology, Engineering and Mathematics (STEM) is encouraged. In this project, the STEM Studio approach was used with school students in formal and informal learning environments for preservice teacher education. Building on research from orchestration and learning analytics identifying stakeholders, and part of a nationally funded, multi-institutional project, we examine the complexity and diversity of communities in three STEM Studios. Using multiple data sources, the aim of this paper is to identify the stakeholders and the relationships between them in order to visualize the complexity of the networks and to compare (1) changes in networks over time; (2) differences between the learning contexts; and (3) the implications for preservice teacher education.

Introduction

Interest is growing in collaborative, constructive, problem-based approaches to learning knowledge and skills in STEM (Science, Technology, Engineering and Mathematics). Studio approaches (Brandt et al., 2013) encourage learners to link core disciplinary knowledge to solve a given problem. With investments by schools and universities in new learning spaces, teachers are incorporating many elements from these informal settings. In order to provide appropriate training for preservice teachers, it is important to understand considerations for the design of STEM units of work, and one important factor is stakeholder collaboration and coordination.

We report on research from a project that investigated the application of studio-based approaches to preservice teacher education using a *STEM Studio* approach. Part of a nationally funded, multi-institutional project, three variations of the STEM Studio are compared: formal education with secondary students; informal education with middle school students; and informal education with primary students. Using video and audio recordings to inform researcher observations, interviews with participants, and questionnaire data, we identify the stakeholders and the relationships between them to visualize: the complexity of the networks; changes in networks over time; differences between learning contexts; and implications for preservice teacher education.

Background

The studio approach to teaching and learning has a history in areas such as architecture or industrial design (Brandt et al., 2013). The studio approach is a variant of project based learning, and core features are iterative design, and self-reflection (Brandt et al., 2013; Hoadley & Cox, 2009). Schon (1987) suggested that this approach could be adopted in any discipline area, and since it has been applied in STEM disciplines (e.g. Shaffer, 2005). The studio leverages opportunities to engage students in rich and open-ended challenges that require and support complex problem solving, application of multi-disciplinary knowledge and fosters the enactment of creative strategies. With teaching more readily considered to be a design profession (Laurillard, 2012), there has been a movement towards adopting a studio approach to preservice teacher education. In this study, we used the studio model to create a "third space" (Zeichner, 2010, p.89) in which pre-service teachers could practice innovative pedagogy and develop pedagogical content knowledge in relation to a range of contemporary STEM topics. The third space provides a temporary learning community for collaborative self-study and professional learning where participants seek new experiences, approaches, and roles in their teaching practice. Using the third space distances preservice teachers from the pressures of assessment of their practice as experienced in both schools and university settings, and encourages collaborative and reflexive practice.

An important factor in the success of studio approaches in informal learning environments is the access to expertise with the creative community. In formal education, this requires stakeholder collaboration and coordination. Research on the design of CSCL has focused on stakeholders related to design and research (e.g. Rose et al., 2016), as well as those related to enactment in the classroom (e.g. Prieto, Dimitriadis, Asensio-Pérez & Looi, 2015). We used an iterative method to identify stakeholders, their influence on the design and enactment phases, and relationships between them (Bryson, 2004). We adopt Goodyear, Jones & Thompson's

(2014) definition of CSCL, which refers to situations in which computer technology plays a significant role in shaping the collaboration, whether online, face-to-face, visualizing activity, or scaffolding learning, and argue that teachers need to be provided with tools to identify stakeholders in STEM Studio approaches, as well as to collaborate during design, enactment, and assessment. We produce stakeholder maps of the relationships before and after the STEM Studios to identify the interactions that exist beyond the peer-to-peer or student-teacher interactions in the classroom. It is this complex network that we seek to capture, with the view to better understand activities such as the STEM Studio approaches, and, more generally, the design work of teachers.

Methods

The STEM studio model was replicated in three university settings in Queensland, Australia, with each setting adapting the model so as to respond to relevant resourcing and demography constraints within each situation: formal education of high school students; informal education of middle school students; and informal education of primary school students. Common to each variant of the STEM Studio model were the interactions in the exploratory third space between STEM experts, mentor practicing teachers and novice preservice teachers.

High school students (formal education) consisted of design challenge based activities within a school based STEM program. The model involved collaboration between classroom teachers, preservice teachers, teacher educators and STEM experts to design, develop and deliver transdisciplinary, problem-based STEM units of work. The design of the STEM units of work was inspired by the core tenets of Universal Design for Learning (Courey, Tappe, Siker & LePage, 2013) and the Exploratorium (The Art of Tinkering, 2015). A core feature was that students, preservice teachers and classroom teachers worked with STEM Experts on contemporary research problems. The STEM Experts included PhD students and academic staff from a range of disciplines (e.g. Astrophysics, Biomedical Science, Civil Engineering, Robotics). STEM experts were involved during the design and enactment of STEM units of work. They collaborated with the preservice teachers via email, phone, and face-to-face to discuss the unit of work, concepts, ideas and real world examples. For each of the 19 STEM Studios offered, one STEM Expert was selected based on the topic area chosen by the school. Each comprised of four meetings, and STEM experts participated in the classroom in at least one of these. *Middle school students (informal education)* involved a structured, out-of-school, STEM enrichment program open to young people in years 5-8 in the district surrounding the host university, in regional Australia. The Commonwealth Government, a local museum, and the local City Council, City Libraries program provided support that included human resources and physical spaces to meet. Preservice teachers volunteered to facilitate the STEM Studio meetings for credit towards community service. Each week, the preservice teachers worked with an experienced STEM educator, supported by a teacher educator who mentored the inquiry-based pedagogical approach, as well as STEM Experts from the fields of medicine, geology and biology who assisted with three of the fifteen weekly activities. Over 15 weeks, 50 school students attended the program. *Primary school students (informal education)*, was carried out in the science teaching labs at the host university. During an existing Outside School Hours Care (OSHC) program, students, years Prep-6, and staff were invited to attend the STEM Studio for up to two hours per week, for eight weeks. The STEM Experts included graduate engineering students. The STEM Experts and the pre-service teacher volunteers were offered training focused on an inquiry-based pedagogical approach. During the STEM Studio, students were given structured information about STEM methods of inquiry, and undertook a design exercise to identify their final project. They formed groups based around common interests and identified three projects: (1) making a three piece ice-cream machine; (2) Bunsen burner investigations; and (3) programming and robotics.

Stakeholder maps were constructed for each setting to depict the stakeholders and interactions before and after the STEM Studio. The maps were created using a process similar to Bryson (2004). The first step was to identify the key stakeholders and rank their importance as major or minor based on time, influence, and support (represented in Figure 1 by the circle size). Researcher observations were used to identify stakeholders, and researchers from each institution discussed and agreed upon the classification in terms of student learning and pre-service teacher education. The second step was to identify relationships between stakeholders and classify these according to personal, professional or occasional (represented on the map by the weight of the line). The identification and classification was determined using the results of questionnaires, interviews, as well as observations by researchers in the STEM Studios as well as video and audio recordings. The stakeholder maps are presented in the results section. Interview data with stakeholders was also used to consider the implications of stakeholder relationships for the design of STEM Studios and pre-service teacher education.

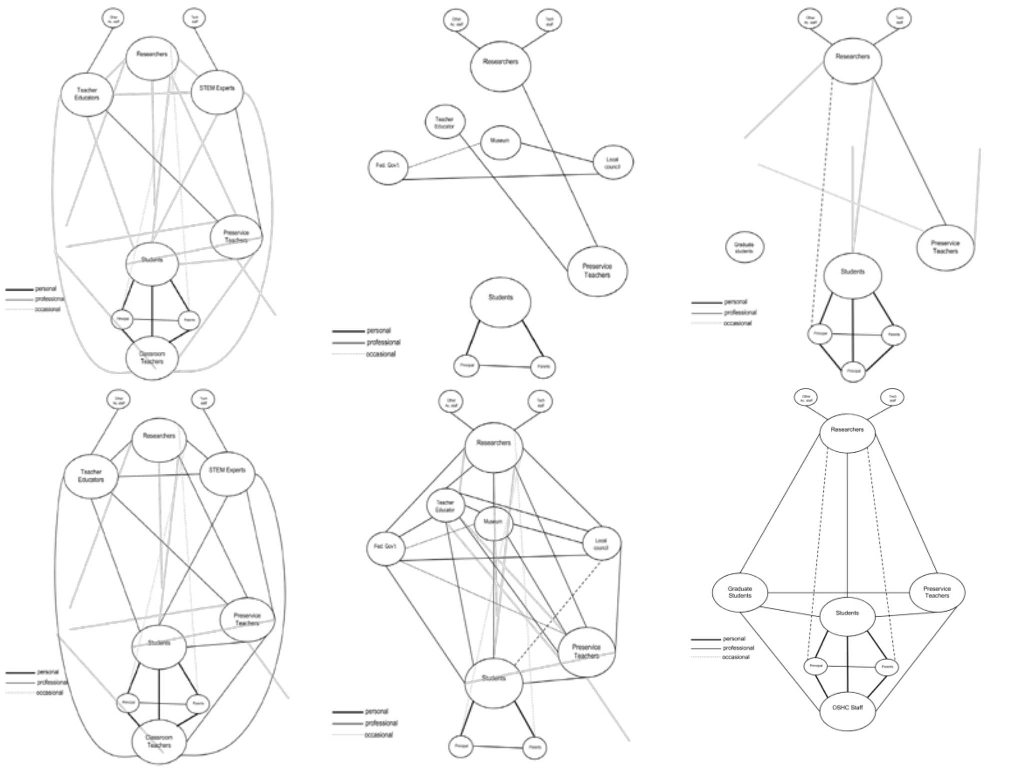
Results and discussion

The stakeholders were identified for each of the STEM Studios in terms of design as well as enactment. The identified stakeholders included individuals from the host Universities (researchers, STEM Experts, preservice teachers, technical staff and teacher educators); schools (classroom teachers, students, principals, parents), and other (Commonwealth Government, Museum, Local Council, and Out of School Hours Care (OSHC) staff).

Each of the STEM Studios was characterized by a different configuration of stakeholders, with influence specific to the purpose of their involvement. The high school STEM Studio included teacher educators as influential stakeholders, the middle school STEM Studio considered the teacher educators to be moderately influential, and the primary school STEM Studio did not include teacher educators as stakeholders. The middle school STEM Studio involved important interactions with other government groups (e.g., museums), whereas the primary school STEM Studio was conducted through the outside school hours care (OSHC) program. Differences between the design phase and enactment were observed in the influence assigned to stakeholders. In the primary school STEM Studio the influence of the STEM Experts was greater during enactment, as were the OSHC staff. The strength of relationships between these stakeholders were then determined These resultant stakeholder maps can be seen in Figure 1, which show the relative importance of the stakeholders by the size of the ellipses and the strength of the interaction by the weight of the connecting lines.

Design phase

Enactment



High school students | Middle school students | Primary school students

Figure 1: Stakeholder maps for STEM Studio contexts, before and after the STEM Studio.

Examination of the design phase maps shows few interactions between the stakeholders. Small, sub-networks existed within institution types, such as the school based networks and that between the community organisations in the middle-school situation. During enactment, the number of relationships increased, as did the complexity of the networks. In addition to highlighting the differences between the designs of each of the three STEM Studio variants, Figure 1 also demonstrates the difference in the focus. In the high school situation, the focus is on preservice teachers. In the middle-school student stakeholder map, the focus is more balanced, with many layers of network. The primary-school student stakeholder map shows the increased influence of OSHC staff and STEM experts, during enactment. The number of connections was expected to be greater during enactment, however, this did not occur uniformly, and the data collected through interviews and questionnaires can help to understand the implications for preservice teacher education.

Initial analysis of the questionnaire data for the high school and primary school situations showed positive changes in preservice teacher self-efficacy after teaching in the STEM Studio, particularly in regard to effective instruction, motivating students and coping with change in the classroom. In both, preservice teachers worked with a variety of stakeholders including experienced educators (classroom teachers and OSHC staff). The importance of the collaboration is supported through the interview data in the high school situation: "This strong collaboration between top scientists, tertiary educators and high school students has been an excellent way to inspire students through engaging in innovative learning activities." (classroom teacher). In the middle-school situation, preservice teachers reported a high level of confidence in developing approaches for communication with school students, but moderate for STEM knowledge and skills, and for pedagogical knowledge related to inquiry approaches. The middle school situation is by far the most complex. Initial attempts to form a STEM Studio without broad community connections were unsuccessful. The resourcing required to initiate and support the STEM studio model could only be realised through a partnership approach. Each of the identified community partners corresponds to a different physical STEM Studio, and the STEM experts at each influenced the learning outcomes identified through thematic coding of the qualitative responses about what students learned. Those at the Museum reported development of knowledge and understanding, while those located at the University reported on a sense of creativity, inspiration and enjoyment, both reported similar identification of learning of skills.

Conclusions

As schools and universities move towards more inquiry and project-based learning approaches to teaching and learning, particularly within the STEM fields and preservice teacher education in the STEM fields, we need to understand the necessary factors for the success of such approaches. We sought to expand our understanding to include the many stakeholders involved. In doing so, we considered the complexity of interactions that teachers need to account for in the design of STEM Studios, and thus, how we prepare them to do so. This goes beyond collaborative teaching, and moves closer to understanding some members of these networks as part of an interdisciplinary team of educators, all of whom contribute expertise about pedagogy, subject matter, or about the learners themselves. We need to prepare our preservice teachers to lead interdisciplinary teams of educators, with computer-based tools to support collaboration, if they are to negotiate the complexity of project-based learning approaches as observed in STEM Studios. Future work will consider these networks of stakeholders in terms of power relationships and the identification, role and impact of key stakeholders.

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