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Designing Boundary Activity for Mobile Learning in Science Inquiry

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Abstract: The importance of learning in informal spaces for science education has been increasingly recognized by the educators and researcher across the countries. In this paper, with emphasis on the value of learning in informal spaces, we propose designing "boundary activity" as the knot for tightening the linkage of learning in informal spaces and formal spaces. Based on literature review, the theoretical underpinnings are articulated for conceptualizing the "boundary object" and defining the components of "boundary activities". The inquiry learning based on the principle of boundary activity is illustrated for informing the curriculum design and implementation in the field of mobile technology supported teaching and learning.

Keywords: Learning in informal spaces, boundary object, boundary activity, mobile technology

1. Introduction

The importance of science learning in informal spaces has been recognized by educators and researchers around the world. Regardless of how they are defined, out-of-school learning experiences have a variety of cognitive, affective, social and behavioral effects that can make a significant contribution to learning (Morag & Tal, 2012). Research findings show that learning experiences in informal spaces can facilitate the acquisition of scientific concepts and the development of inquiry skills, as well as stimulate motivation. Educational documents (e.g. curriculum standards) also endorse teaching and learning practices in informal spaces. However, there is a limited number of successful programs or projects that integrate the merits of learning in informal spaces with formal learning. Nor have the existing programs been rigorously examined. Meanwhile, teacher competency in designing and implementing learning activities in informal spaces further hampers best practice of such learning. The result is an increasing gap between formal learning and learning in informal spaces. Although the ubiquitous use of mobile technology creates various opportunities for connecting the formal learning process with informal spaces, the record of success is limited in terms of curriculum design and implementation. Additionally, there is inadequate documental support (i.e. science curriculum standards, teaching materials, online resources) on best practices for connecting formal and informal contexts with mobile technologies. This constrains the sustainability and scalability of such learning and teaching practices.

To address these issues, the paper will focus on the conceptualization of boundary object and boundary activity for connecting the merits of learning in informal spaces with formal learning, as relates to inquiry-based science learning. A lesson exemplar will be shared with the purpose of illustrating how the principle of boundary activity can be applied in science learning design with the use of mobile technology. The research will be the first one to consider the boundary activity in the field of mobile learning for establishing the connection the learning between formal and informal spaces. In boundary activity, the students' interactions with informal learning spaces will be the integral part rather than the supplementary part of the standard curriculum. This will transfer teacher and students' perspectives of learning in the informal spaces, and inform the science instruction supported by technology.

2. Theoretical Underpinnings

The researchers have recognized the importance of getting insights into the mobile learning in the informal context, but challenges on the curriculum design and implementation, as well as the assessment of students' learning still exist. Jones and two others found that there is little literature that considers the structures needed to support informal and semi-informal inquiry learning (Jones, Scanlon, & Clough, 2013). Mortensen & Smart (2007) points out that although there is a growing effort to create partnerships between schools and informal learning settings, documentation of such projects is limited, and generally reported as examples of "best practice" with little discussion of challenges before or during implementation. In this section, the concept of boundary object is further coined in the field of mobile learning. The principle of boundary activity is defined and discussed. The principle will help the educators and teachers to better fit students' learning in informal spaces into the formal learning context, with establishing the boundary objects and conduct boundary activities.

2.1 The Conceptualization of Boundary Object

To improve connecting learning in formal space with learning in the informal spaces, boundary object is the proposed as the "knot" for linking the learning in these two contexts. Boundary object, a term which has been discussed in science education. It refers to the common idea generated in scientific work which needs cooperation with among divergent viewpoints and the need for generalizable findings (Star & Griesemer, 1989). It can be either abstract or material, for example, field notes, specimens and artifacts which can be the connections between formal learning and learning in the informal spaces.

In a more elaborated definition from Wenger's study (Wenger, 1998), boundary object is one type of the connections between communities of practices, namely, artifacts, documents, terms, concepts and other forms of reification and around which communities of practices can organize their interconnections. Tsurusaki, et al., (2012) created "transformative boundary objects" and explored how the transformative boundary objects work in the teaching practices of a teacher with the aim of engaging students in science learning. Three types of boundary objects were discussed: bar graph, research questions and nutrition in the teaching of healthful food. In Gilbert and Priest's (1997) study, they discussed some external factors for promoting the effectiveness of students' museum visits and attempted to link their informal learning experience with the topics learned via formal learning. They organized group activities for students to discuss the "critical incidents" in the visits, and meanwhile pre-, during and post activities were designed for students to elaborate their knowledge in and out of the classroom. In this case, the critical incident is the boundary object. In brief, boundary object can be an abstract concept introduced in the classroom and elaborated outside of the classroom, or a guiding question related to a key concept. It can be an event or a science phenomenon which requires students to investigate outside of class and discuss in class. The boundary object can also be a physical object which is generated in or outside of the classroom. In sum, as a metaphor, boundary object is the physical or abstract objects generated by the interaction between boundary of formal and informal spaces, which may play an important role in students' science learning in various contexts, especially for the outsides activities. Once integrated with the use of mobile technology, there will be more physical representations of boundary objects, for example, concept maps, drawings, photos, videos, notes, etc. and there also will be more opportunities for students to engage in discussing, responding to questions and sharing boundary objects.

2.2 Principles of Boundary Activity

Kisiel (2014) proposed that joining resources from both formal and informal learning settings is an effective strategy that enhances students' interest in science and STEM (Science, Technology, Engineering and Mathematics) learning. He used a term "boundary activity" to define the activities which connected schools and informal science institutions. The term of boundary activity refers to "those encounters between schools and ISEIs (museums, science centers, aquariums, and the like) that involves some kind of designed program-field trip, outreach, and teacher workshop with specific educational objectives". In his viewpoint, boundary activity is the mediation for the interaction between the existing/original communities. The connection established by boundary activity is a deeper, practice-based interaction which has potential to better facilitate interaction between the two communities. The creation of the joint practice-based enterprise is highlighted. It is an enlightened term that enables us to think about what these boundary activities look like in the view of curriculum development? What are the best boundary activities serving for the specific purposes in science teaching and learning? What is the mutual interaction between formal learning and learning in the informal spaces in the boundary activities? Based on the above ideas, we define boundary activity as the learning activities which take place in either formal or informal contexts, and contain at least one boundary object that bridge learning in formal and informal environments.

We continue to get more insights into the findings of the relevant studies for carving the conception of the boundary activity. Rickinson et al. (2004) demonstrated that if field activities were 'properly conceived, adequately planned, well taught and effectively followed up', they could offer 'learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom'. Similar findings were found that when teachers did focus pre-visit preparation of the informal institution, there was an improvement in student learning and attitude (Patrick, Mathews, & Tunnicliffee, 2013; Gilbert & Priest, 1997). Mike Sharples (2014) proposed to employ scripted learning methods to conduct outside inquiry activities. In his study, the teacher initiated a structured activity with the mobile devices inside the classroom, and then each pupil continued the investigation outdoors. Results were then shared, discussed and presented back in class. Falk and Balling (1982) at very early time mentioned that without orientation and preparation, students were more likely to concentrate on non-relevant aspects of the surroundings, rather than those relevant to the learning intended. Specifically, Patrick et al., (2013) thought that field trips need to incorporate problem-solving skills, be tied into the curriculum, focus on the standards, and take into consideration the children's needs. Thus, with more efforts on designing and implementing boundary activity in structural way, the teaching for learning in informal spaces will be more efficient.

Therefore, we propose three components of a boundary activity: boundary object, structure and learning Objectives based on above literature. We refine the idea to delineate between boundary object, activity structure and learning objectives: (1) The boundary object is a prerequisite for designing the boundary activities. It acts as a knot which serves to bridge learning in and out of the classroom and capture the learning process in the informal spaces. With boundary objects, the boundary activities will better fit into the standard curriculum. (2) Structure: the boundary activity is conducted in the pre-, during- and post-activity pattern to guarantee the continuum and stability of cognition or skills developed across the learning contexts. (3) Learning objective: the learning objectives of boundary activity should be defined based on the curriculum standard and the characteristics of the contextual variables in practice. These three components are proposed to guide the design and implementation of a boundary object. Figure 1 represents the structure of boundary activity and the interaction between formal learning and learning in informal spaces. The boundary activity is conducted across the formal space and informal spaces. It is usually prepared and instructed in the formal learning context (i.e. classroom) prior to carrying out it. With mobile devices, data, evidence and any responses related to the tasks of boundary activities generated in informal spaces can be the representative boundary objects, prompting the boundary interactions taking place.

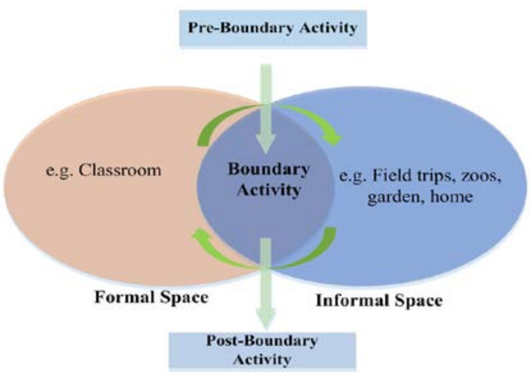

Figure 1. The principle of boundary object

3. The Medium for Running Boundary Activities: nQuire-it and WISE

In implementing boundary activity, we envisage the use of a stable and multifunctional system to support students in-classroom activities and out-of-classroom activities, and capture interactions of students and their teacher in the various contexts (i.e. online & authentic learning, in classroom & out of classroom). Two web-based platforms will be integrated in boundary activity based learning: nQuire-it (http://www. nquire-it.org) which facilitates students' inquiry activities in informal spaces, and WISE (https://wise.berkeley.edu/) which guides students' online inquiry in a step-by-step manner. Figure 2 represents the overall picture of the roles nQuire-it and WISE play in boundary activity. In comparison of other sensor-based technologies, nQuire-it is a learning platform which is more suitable for conducting outside activities in either guided inquiry or open inquiry, and either in an individual or collaborative way (Llewellyn, 2007; Wenning, 2005). Specifically, it supports students to collect real time data outside (ie, real experimentation, hands-on activities, home activities, field trips, etc) using Spot-it (a mobile tool for capturing images and annotating things with notes) and Sense-it (a sensor-based mobile tool for collecting and sharing data using phone sensors: accelerometer, gyroscope, light and sound, etc). Thus, the use of nQuire-it will particularly enhance students' interaction with the informal learning spaces for testing their hypotheses and deepening understanding through authentic learning activities. In this case, the real-time data in the form of photos of scientific phenomena and graphs are the major boundary objects. The activities for planning, conducting data collection and sharing are the boundary activities. As a learning management system (LMS), WISE provides teachers with a powerful authoring tool to design guided inquiry-based activities. With the use of WISE, the learning taking place taking place in formal spaces and informal spaces can be merged into this system. A WISE lesson facilitates students' online investigation of simulation, videos and virtual labs in and out of the classroom (Slotta & Linn, 2009). The WISE system provides various learning tools, such as a drawing tool, concept map tool, simulations, peer discussion tool and others to support student learning and communication in and out of the classroom. As a result, students receive more opportunities to investigate in the virtual contexts and report their findings online. More importantly, teacher-student and student-student interaction, students' responses, teacher feedback and assessment can be traced and recorded as evidence of students' performance. nQuire-it can be flexibly inserted into the learning design of WISE lessons. In this Hong Kong-based study, the synergic use of nQuire-it and WISE enables students to investigate both the virtual and authentic scientific phenomena and to interact with their teachers and classmates any time anywhere.

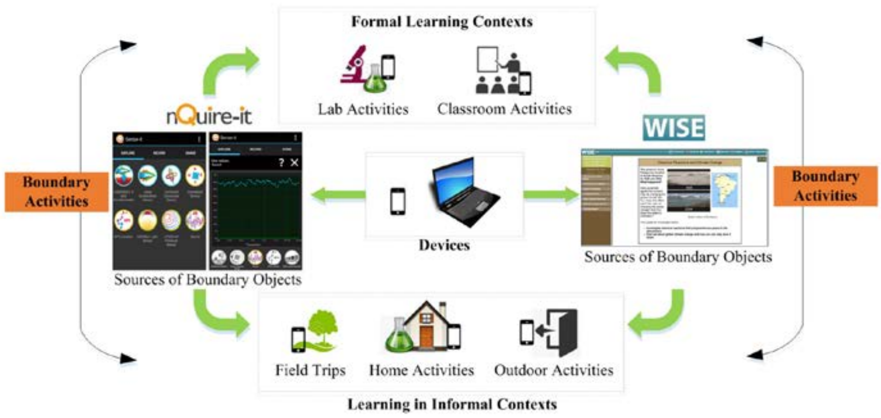

Figure 2. Boundary Activties supported by mobile technology

4. Lesson Exemplar of Boundary Activity based Science Inquiry

Table 1 shows a lesson exemplar based on the principle of boundary activity and inquiry based learning. The topic is Energy, from the Hong Kong General Studies (Primary 6). In the lesson, four inquiry phases consisting of Questioning and Context, Sense-it Exploration, Sharing and discussion, Summary and Reflection are organized by the WISE system and the nQuire-it platform. The step-by-step manner facilitates students' inquiry learning in an explicit manner. The principle of boundary activity is integrated in the design of inquiry phases. In the pre-boundary activity stage (Questioning and Context), students are provided with instructions of tasks and guiding questions. During the boundary activities (Sense-it Exploration), students are engaged in a series of hands-on activities with mobile devices: collecting data, uploading data, reviewing data and doing peer assessment. In post-boundary activities (Sharing and discussion), students' work is further discussed and assessed in class. Finally, they consolidate their understanding and respond to the guided questions in WISE system (Summary and Reflection). Through these kinds of activities, the teacher will have a clearer picture of how a boundary activity should be conducted, and what are the boundary objects (i.e., guiding questions, data chart of sunlight), as well the purposes of the post boundary activities (i.e., requiring doing higher cognitive levels of activities). And they will conduct learning in formal spaces in more structural way.

Table 1. The lesson exemplar of boundary activities

Inquiry phase	Content	Learning spaces	Boundary Activities
1. Questioning and Context (WISE)	Solar power is a clean energy. It is one of important resources for human being to obtain the electricity. Working with you group members to answer the following question: Which is the best time/time slot for us to make use of the solar power in daytime?	Classroom: Teacher assigns tasks and introduces the tasks with details in the classroom.	Pre-boundary activity
2. Sense-It Exploration (nQuire-it platform)	Using Sense-it to collect data of sun light and upload the data chart and share the evidence with classmates. The students are also required to comment on each other's work.	Outside and home: Students collect data outsides and upload the data chart via Sense-it and review their classmates' work and comment their work at home.	Boundary activities
3. Sharing and discussion (WISE and nQuire-it platform)	Teacher presents all students' work uploaded in nQuire-it platform, and identifies the quality of work and discuss with the students.	Classroom: The discussion and interaction focusing on the boundary objects in classroom.	Post-boundary activities
4. Summary and reflection (WISE)	The students summarize the science phenomena of sunlight by responding to the guiding question.	Classroom or home: The summary and reflection enable students to elaborate on their understanding of solar energy.	Post-boundary activities

5. Conclusion and Future Research

In the paper, the conception of boundary activity is further coined in the field of mobile learning. The key elements of the boundary activity have been refined. The boundary object has been identified. The pedagogical principle of the boundary activities is incorporated into the design of mobile-technology supported science learning activity. Hence, the research will be a deeper attempt on the integration of curriculum development, mobile learning and learning in informal spaces in science. This will inform the science curriculum design and development supported by mobile technology.

Hofstein and Rosenfeld (1996) contended that "it would be useful if science educators would consciously utilize a wide range of out-of-school environments which foster science learning". They preferred to adopt the "hybrid" view (rather than the dichotomy) that informal learning experiences can occur in formal learning environments as well as informal learning environments. They recommended that future research in science education should focus on how to effectively blend informal and formal learning experiences to significantly enhance the learning of science. The proposal of learning design based on boundary activity is the appropriate direction for addressing this.

In the future research, we will focus on unfolding the transformative process of students' scientific concepts, inquiry skills and collaborative learning skills impacted by the boundary activity, snapshotting the reciprocal interaction between formal learning and learning in the informal spaces, finally changing teacher and students' perspectives of the learning in the informal spaces and to enhance teacher competency on conducting learning activities in the informal spaces.

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References

Falk, J. H., & Balling, J. D. (1982). The field trip milieu: Learning and behaviour as a function of contextual events. *Journal of Educational Research,* 76(1), 22-28

Gerber, B. L., Cavallo, A.M.,& Marek, E. A. (2001). Relationships among informal learning environments, teaching procedures and scientific reasoning ability. *International Journal of Science Education*, 23(5), 535-549.

Gilbert, J., & Priest, M. (1997). Models and discourse: A primary school science class visit to a museum. *Science Education*, 81(6), 749–762.

Jones, A., Scanlon, E., Mark, G., Ganan, B., Trevor, C., Gill,C., Lucinda, K., Karen, L., Paul. M., Marilena, P., & Alison, T. (2013). Challenges in personalisation: supporting mobile science inquiry learning across contexts. *Research and Practice in Technology Enhanced Learning,* 8(1), 21-42.

Hofstein, A., &Rosenfeld, S. (1996). Bridging the gap between formal and informal science learning. *Stuides in Science Education*, 28(1), 87-112.

Kisiel, J. F. (2014). Clarifying the complexities of school–museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching*, 51(3), 342–367.

Llewellyn, D. (2007). Inquire within: implementing inquiry-based science standards in grades 3-8. Thousand Oaks, CA: Corwin.

Patrick, P., C. Mathews, et al. (2013). Using a field trip inventory to determine if listening to elementary school students' conversations, while on a zoo field trip, enhances preservice teachers' abilities to plan zoo field trips. *International Journal of Science Education,* 35(15), 2645-2669.

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M.Y., Sanders, D., & Benefield, P. (2004). A review of research on outdoor learning. Shrewsbury: National Foundation for Educational Research and King's College London.

Sharples, M., Scanlon, E., Ainsworth, S., Anastopoulou, S., Collins, T., Crook, C., O'Malley, C. (2014). Personal inquiry: Orchestrating science investigations within and beyond the classroom. *Journal of the Learning Sciences*, 24, 308–341.

Star, S. L., & Griesemer, J. R.(1989). Institutional ecology, translation and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science*, 19(3), 387–420.

Tsurusaki, B. K., Calabrese Barton, A., Tan, E., Koch, P., & Contento, I. (2012). Using transformative boundary objects to create critical engagement in science: A case study. *Science Education,* 97(1), 1–31.

Wenning, C. J. (2005). Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *Journal of Physics Teacher Education Online*, 2(3), 3–11.

Wenger, E. (1998) Communities of practice: learning, meaning, and identity. New York: Cambridge University Press.