Towards A Framework for Seamless Learning Environments

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Abstract: As mobile devices and network access become more pervasively available, researchers are becoming interested in seamless learning environments (SLE) that bridge informal and formal learning. Learners are engaged in learning while moving across different physical and social spaces mediated by technology in a SLE. Researchers face theoretical and methodological issues in understanding seamless learning and designing seamless learning environments. Based upon our work in designing a learning environment using mobile devices and online portal for environmental education and inquiry-based science learning, we identified several components of seamless learning environments: Community, Space, Time, and Context, Cognitive Tools, and Artifacts, Using the components, we propose a framework built upon the theory of Distributed Cognition for seamless learning. (116 words)

Introduction

As mobile computing devices and network access become more pervasively available, researchers have become increasingly interested in seamless learning environments (SLE) that bridge formal with informal learning. Learners are engaged in learning while moving across different physical and social spaces mediated by technology in a SLE. Some important questions emerged: how does learning in a formal context prepare students for learning in informal contexts, and vice versa? What theoretical lens do we have in looking at the seamless transitions? How to design and provide scaffolding in such SLEs? How to facilitate and assess student learning in such environments? What are the implications for learning to occur across the "boundaries" in the "flat" world? (Friedman, 2005) There are theoretical (Sharples, Taylor, & Vavoula, 2007), methodological, technological, and practical (Chan, et. al., 2006) issues which need to be addressed in order to help researchers and educators to understand seamless learning, and create pedagogical strategies to exploit the use of seamless environments for teaching and learning. We would like to share our perspectives on research in seamless learning environments based on two projects which we designed. The first project we present will be the 3Rs project, which has components of seamless learning environments bridging classroom experiences and field work; individual, group and class discussions, and school and home experiences. We reported good learning outcomes at the end of the project where the students gained better conceptual understanding of the 3Rs (Reduce, Recycle, and Reuse) and put into practice what they have learned (Zhang et al, 2006; Seow et al, 2007; Tan et al, 2007). The second project was to design and implement a sustainable and scalable seamless environment for students, to acquire inquiry-based process skills through the use of mobile devices and online technologies integrated into the school science curriculum. From the two projects, we identify components in seamless learning and propose a framework for designing and analyzing seamless learning environments.

3Rs – A Primary Environment Education Project

We worked with 6 primary schools in a project to help 480 students learn about environmental issues through the concepts of the 3Rs – Reduce, Reuse, and Recycle. The activity was co-designed with the teachers of the schools. It spanned over duration of two weeks where the students engaged in various phases of experiential learning and in different places such as the classroom, supermarket, fast-food restaurant, and computer labs. Table 1 shows the seamless learning activities occurring over time and different locations.

Table 1: Seamless Learning Activities.

Activity	Day	Location	Description
Challenge – Articulating the problem	1	Classroom	The teacher gave a short introduction to the problem of having too much garbage. Students created KWL* tables and shared with each other about their learning objectives (1 hour)
Experience – Field Activity	5	Supermarket and Fast Food Restaurant with wireless network	Three activities that students performed at a supermarket: 1. Study different sizes and materials for packaging and take photos of the products; 2. Observe how many plastic bags are dispensed at the checkout counters within five minutes; 3. Interview customers about their attitudes and practices of 3Rs; (2 hours) Students uploaded their data collected during the field trip at a fast food

Activity	Day	Location	Description
			restaurant using the wireless network (10 minutes)
Reflecting and Planning - Post Field Activity 1	7	Computer Lab	Student provided feedbacks to each other's data collected and posed questions to environmental experts (1 hour)
Applying - Post Field Activity 2	14	Classroom	Student groups presented to the whole class about how their groups have designed artifacts for promoting 3Rs ideas and getting feedback from the class (1.5 hours)

K = What I know, W = What I want to know, L = What I learned

The use of mobile devices equipped with a built-in camera, online portal, network access in the school, and wireless connectivity in the fast food restaurant provided a seamless environment for the students to move information from physical environments outside the classrooms to the school computer lab. A mobile learning software application was designed to guide the students in the experiential learning cycle shown in Figure 1. Students are able to use the software to collect data, capture images, and write their observations throughout the different phases. For example, they use it to record the number of plastic bags given out in the supermarket as shown in Figure 2. The Apply phase in the cycle let the students enter the results of their plan in Figure 3.

Figure 1. Learning cycle as structure

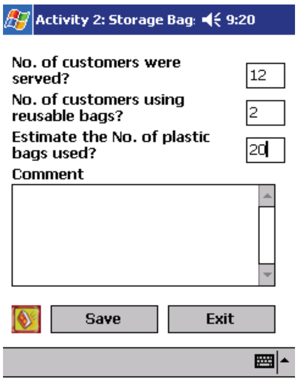


Figure 2. Students collect data on the mobile device

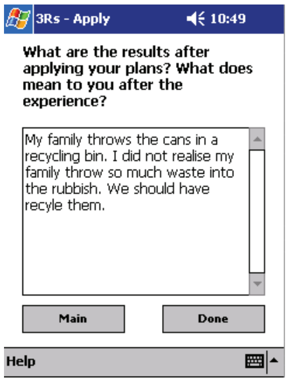


Figure 3. Students write their results in the mobile device

We conducted a study on 81 students comprising two classes of students from two of the six participating schools. Due to the limited number of mobile devices, one device was shared by a group of four students. The motivation of the study was to understand the learning outcomes of the seamless learning environment and how effective it was in helping students learn about the 3Rs. We conducted pre-tests and post-tests for all students to find if the student gained a better understanding of the 3Rs concepts. Researchers also followed the students acting as non-participant observers recording the interactions of research target groups. In each class, two groups of four students were selected as the target groups for closer observations. They were interviewed to understand their experience and learning outcome.

The results from the pre- and post-tests were positive and encouraging. In the pretests and post-tests, the students were asked about the extent they know about the 3Rs. There was an increase of 16% in the number of students reporting they know the 3Rs in details while there was a decrease of 12.3% in the number of students who "do not know the details". The students' self-reported data was validated by their answers to the open-ended questions on their understanding of the 3Rs. They had to articulate the 3Rs with questions like "What do you understand by Reuse?" and they had to give as many examples as possible. The results showed there was a significant improvement in student conceptual understanding of Reduce and Recycle, and the number of examples provided for Reduce, Reuse, and Recycle.

Table 2: Examples of responses to open-ended questions on the understanding of the 3Rs.

Area	Student	Pretest	Posttest
Recycle	Student 1	I make use of something and make another thing. I use newspapers to make origami and display it in my house	It means to make use of something that is **unwanted or used to make another new product**. Using old newspapers to make into new white paper.
	Student 2	Give newspaper to the newspaper man	**Recycle means transforming something not in use** to something better. Newspaper can be recycled to form paper.

Reduce	Student 3	Reduce means to use less to me. Use a pail to wash the car.	Reduce means **cut down of using things. Use reusable bags instead of plastic bags**
	Student 4	Reduce means try not to use much. Like reduce littering on the floor.	It **means cut down. Reduce using plastic bags**
Reuse	Student 5	Reuse means to use again. Like to use the water to wash a car after you use it to wash clothes	It means to use again for the same or **other purpose**. **To use the same plastic bags or bottles again.**

Our interviews with the students revealed that some of them were able to apply the 3Rs into their own homes by influencing their parents on the need and practices of conserving the environments. As shared by one of the students,

> "My family does not actually use reusable bags. It is always my mom who does shopping. Yesterday I told my father you should use and can always encourage my mom to use more reusable bags. He agreed with it and then he said that but sometimes we have a lot of things so we need to have some plastic bags to use. Sometimes we can keep these plastic bags."

Another two students mentioned the change of their parents' shopping habit: "They will bring reusable bags when they are shopping. They didn't not do it before", "They recycle plastic containers now!" One student talked about the recycling plan: "At home we use a mineral water bottle, we cut out… put a paint brush inside there that I can use that one to paint".

We accessed the discussion forum and the report uploaded from the mobile device to the class online portal to understand the relationship between the artifacts, reflections and questions generated by the students. The kinds of experiences and artifacts students pursued while doing the field activity mediated by their mobile devices stimulated certain kinds of reflections, questions and concerns. Table 3 shows some samples collected from the groups.

Table 3: Artifacts, reflections, and questions generated by some groups.

Group	Artifacts	Reflections	Questions
Group 1	Picture of a plastic biscuit packaging Estimated 13 plastic bags used at counter Interviewed 6 customers.	"We must use reusable plastic bag and recycle things when possible" "Most people use plastic bags then to bother to bring their own reusable plastic bags."	How can we reduce the usage of plastic bags?
Group 3	Pictures of a plastic, paper and metal biscuit container. Recorded observation that 2 customers used 14 plastic bags.	"Most people are using plastic bags. None of them are using reusable bags."	How long does plastic take to decompose?
Group 2	Pictures of Milk Tetra Pack and a Low Fat Milk Plastic container Recorded observation that no customers were using reusable bags Comments from interview: "She thinks that bringing shopping bag to the supermarket is very inconvenient."	"Lots of people used plastic bags but none used shopping bags."	"How are plastic bottles recycled?"

Mobile Devices for Science Inquiry-based Learning

The important learning objectives of science education are three-fold: science knowledge, inquiry and reasoning skills, and the nature of science (Perkins, 1986). Based on our previous work on Project 3Rs, we sought to design a seamless learning environment to help early learners of science in primary schools to acquire the above objectives. First, a seamless leaning environment similar to Project 3Rs can provide a scaffolding tool to improve students' processing skills. Second, through the use of mobile devices and online technologies, students can create, modify, or extend various representations or artifacts for learning. Thirdly, individual learners are connected to other learners in the community where they can share their artifacts, collaborate with others, and ask questions on the data. To create a more sustainable and scalable environment which can be integrated into the school science curriculum, we created an application which teachers can create, share and modify inquiry-based lessons for the seamless learning shown in Figure 4. Our purpose was to create templates on mobile devices and web portals for teachers to easily create a variety of inquiry-based learning projects in the school. They can be shared and reused. Figure 5 shows the inquiry learning path on the mobile device. Students will follow the inquiry path in the following sequence: Challenge, Plan, Experience, Conclusion, and Reflection. Figure 6 shows Reflection phase where students reflect on the inquiry process guided by questions created by the teacher. Students can upload their data over to an online class portal where they view the data collected by other students, raise questions for discussion, and modify their own conclusion based on their own data and that of their class. The online portal provides a platform where students can move from the individual space on the mobile devices to the public space to facilitate collaboration and sharing.

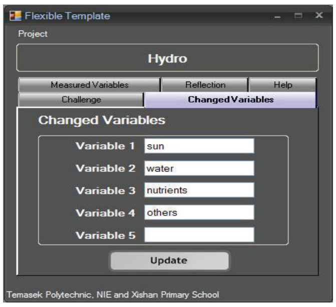


Figure 4. Desktop application for teachers to create, share, and modify inquiry based lessons.

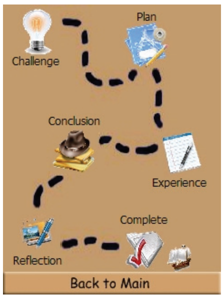


Figure 5. A structured inquiry path on the mobile software.

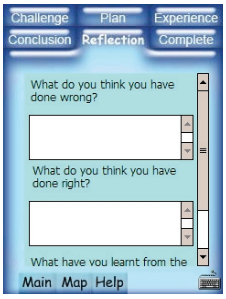


Figure 6. Students entered their eflection on inquiry process.

As a follow-up to the 3Rs project, we are currently implementing the environment in a Primary school and have yet to complete our research on the outcomes in inquiry-based learning. We plan to collect multiple data sources including pre- and post content tests, surveys of student attitude and perception change, student artefacts and online posts, interviews, videos during classes and/or field trips will be used to help us better understand the cognitive processes in a seamless learning environment, and compare the learning between controlled and experiment groups.

A Framework for Seamless Learning

Our initial pilot work in the 3Rs project suggests that a suitable lens for interpreting seamless learning activities is the distributed cognition (Hollan, Hutchins, & Kirsch, 2001). In a seamless learning environment, learning takes place through individual learning in private spaces, collaborative learning in public spaces, and artifacts created across time and physical or virtual spaces mediated by technology within a context (Sharples, 2006; Chan et al, 2006).

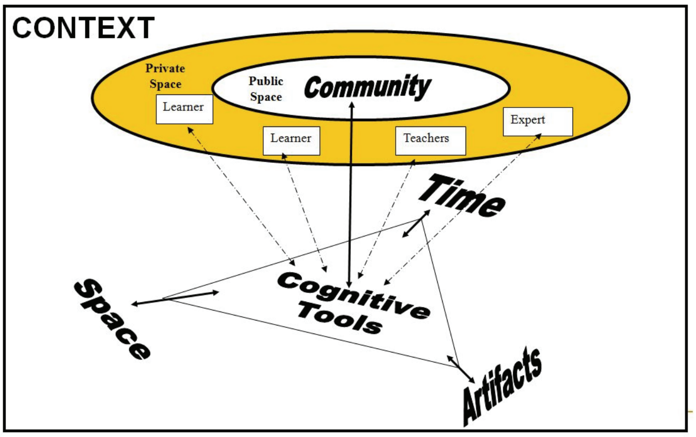


Figure 7. Seamless Learning Framework.

Distributed cognition can provide a framework on understanding how learning occurs through the interactions of students, artifacts, and the environment mediated by technology over space and time. It has been used as an analytical framework for studying the navigation of ships (Hutchins, 1995), cockpit operations in airplanes (Hutchins, 1995), and design processes in construction engineering (Perry, 1997). Though the studies was to understand how teams comprising of individuals with different skills or assigned roles function together to achieve a specific task, there are applications to learning as expertise and students' interactions are also distributed in the classroom (Pea, 1993; Brown, et. al., 1993). Hollan, Hutchins and Kirsch (2001) proposed three principles in which cognitive processes occur: They are distributed across the members of the social group; over time; and coordination between material or environmental structures in the system. Learners interact with the environment in the community, artifacts, activity, and space through the cognitive tools to form a joint learning system (Kim & Reeves, 2007). Based on our identification of components in a seamless learning environment and the theory of distributed cognition, we proposed a framework shown in Figure 7.

Components in Seamless Learning

We identify several components which may contribute to the learning within a seamless environment: Space, Time, Context, Community, Cognitive Tools, and Cognitive Artifacts.

Space

Seamless learning suggests that the learners can move seamlessly between different spaces – physically and virtually. The use of mobile devices in a seamless learning environment can "affect accessibility as well as the sharing of ideas and engagement in co-constructed activities among students" (Bielaczyc, 2006). The physical space where students use to conduct inquiry with the mobile device can be used as a resource for learning (Milrad et al, 2004; Squire & Kopfler, 2007). Students can also engage one another through the virtual space such as online forums as shown in Figure 8.

Time

Over time, when learners operate on artifacts, collaborate with peers, teachers and experts or conduct in discovery, they acquire and build knowledge (Hewitt & Scardamalia, 1998). In the project, interactions between peers, technology, and artifacts (e.g. photos taken during their field trip) shape their conceptual understanding of the 3Rs and even lead them to apply their knowledge. Time can play an important role in shaping and evolving inquiry (Latour, 1987) in a seamless learning environment.

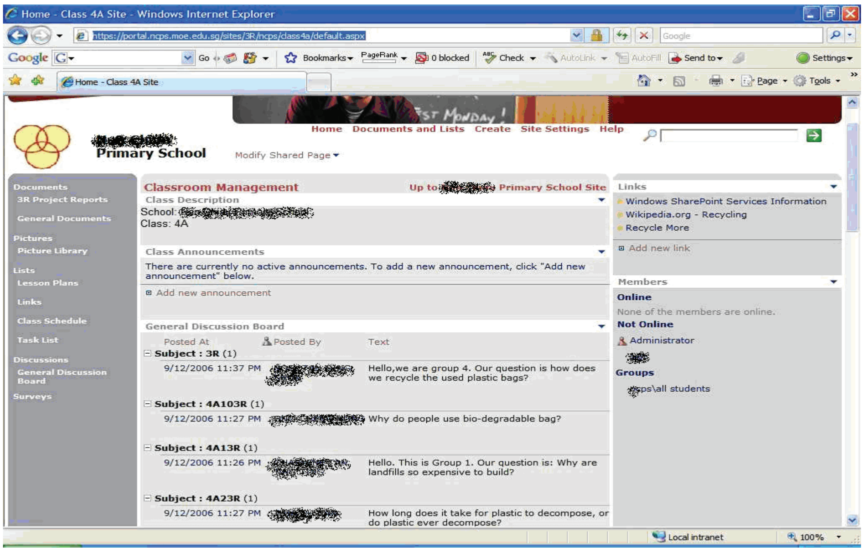


Figure 8. Online discussions showing the questions posted by the students

Context

The context of the designed activities impacts their learning, application, and plans. For example, students in the post-activity interview seem to cite about the problems of excessive use of plastic bags which lead them to try influencing their family. This could be attributed to the student's observations of the plastic bags used at the check-out counter of the supermarket and their interview of shoppers. The observations and interview experience with the collected data provided the students with a strong perception that plastic bags in Singapore are causing wastage in the environment. In activity 1, students were asked to collect data on the type of packaging that could reduce waste. None of the students observed or reflected that some manufacturers excessively package their products causing wastage. If they could go to a factory to see how the wrappers and containers were produced, they might be able to understand how packaging consumed resources and created waste better. The context of wastage of plastic bags made a stronger connection to the students than compared to the context of packaging, leading them to apply what they have learned.

Community

The community in a seamless learning environment comprises of learners, teachers, and domain experts. Community-based learning environments such as Knowledge Forum (Scardamalia & Bereiter, 1994) have shown how individuals contribute to the building knowledge within the community. Individual learners in a seamless learning environment can move from individual learning to community learning on the online portal we created. Students discuss with one another on the data, findings and raise questions. In Project 3Rs, examples of questions asked by students on the online portal are "How long does it take for plastic to decompose, or do plastic ever decompose?", "Our question is how do we recycle the used plastic bags?" and "Why are landfills so expensive to build?"

Cognitive Tools

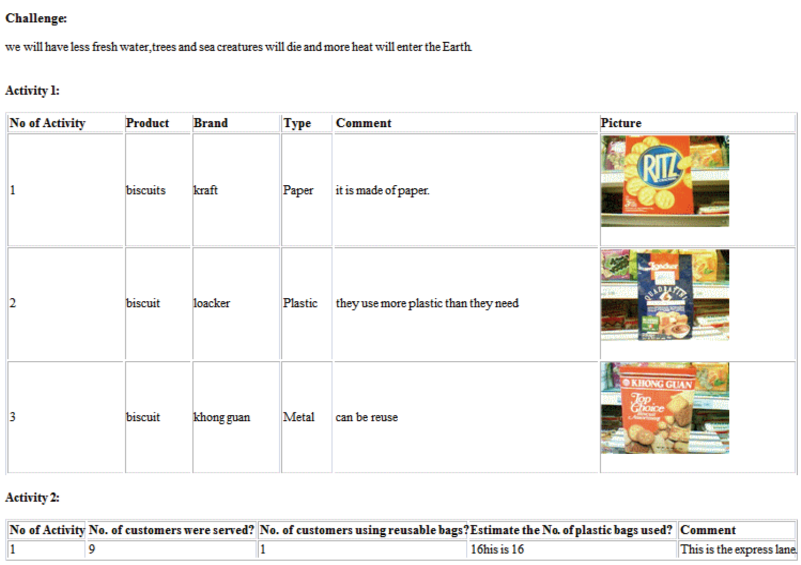
As students use the mobile device to record data, capture images, upload data to the online portal and reference them, mobile devices and online portal become cognitive tools where they are able to offload tasks, recall information over time, and modify their initial thoughts. As shown in Table 4, Jonassen and Reeves (1996) identified some criteria for cognitive tools 1) scaffolds intentional learning and meta-cognition 2) allows student to create knowledge 3) engages student in critical thinking about subjects 4) significantly restructures or amplifies thinking and 5) facilitates collaboration and distributed cognition.

Table 4: Mapping of criteria of cognitive tools to the affordances in seamless environments.

Criteria	Affordances in Mobile Devices and Online Portal
Scaffolds intentional learning and meta-cognition	Experiential and inquiry cycle provides a structure for students to follow in the mobile device in the leaning activity
Allows student to create knowledge	Students collect data, write their plans, reflect on the data using the mobile device.
Engages student in critical thinking about subjects	Students can reflect on the data saved on the mobile device or online portal
Restructures or amplifies thinking significantly	Students can modify and share the data both on the mobile device and online portal can help them to restructure some of their understanding, clarify their thinking with others and promote inquiry by raising questions.
Facilitates collaboration and distributed cognition	Mobile device and online portal facilitates collaboration and distribution cognition over artifacts, across activities, across the community over time and space.

Artifacts

Important components of a seamless learning environment are the artifacts created by students. An artifact can "maintain, display, or operate upon information in order to serve a representational function" (Norman, 1991). In our 3Rs and science inquiry-based environments, students can create artifacts both on the mobile device and online portal. Data such as the number of plastic bags dispensed at the check-out counters, observation information of colour of the leaf on the plant, or images captured of the plant growth on the fourth week on the mobile device camera are cognitive artifacts collected on the students. One affordance of mobile devices is the ability to consolidate different artifacts to create aggregated or consolidated representations or views as shown in Figure 9. The consolidated view can be uploaded to the online portal from the mobile device through the network. On the online portal, the artifact can be viewed by other students to foster sharing and collaborative learning. There is potential in developing tools which allow students in a class community to index, search, retrieve and share artifacts through knowledge organization of such artifacts.



Challenge:

we will have less fresh water,trees and sea creatures will die and more heat will enter the Earth

Activity 1:

No of Activity	Product	Brand	Type	Comment	Picture
1	biscuits	kraft	Paper	it is made of paper.	
2	biscuit	loacker	Plastic	they use more plastic than they need	
3	biscuit	khong guan	Metal	can be reuse	

Activity 2:

No of Activity	No. of customers were served?	No. of customers using reusable bags?	Estimate the No. of plastic bags used?	Comment
1	9	1	16his is 16	This is the express lane.

Figure 9. Consolidated view generated by the mobile device.

Future Work

In this paper, we propose a framework of seamless learning based upon our ongoing efforts in designing a seamless learning environment. We plan to refine the framework with our ongoing implementation and research on the seamless environment for fostering inquiry-based learning. Indeed, small mobile devices make it affordable for young students to have one or more devices. It is also possible to have integrated inquiry activities at primary school level that might involve multiple subjects such as language, math, science or social sciences. As more schools embark on 1:1 technology-enhanced learning initiatives and innovations, we see great potential to apply our framework for seamless or ubiquitous learning. Here are some questions that we hope to discuss with the learning sciences community: 1. How can we construct sustainable seamless learning environments? Should we start from formal school settings or should we look at emerging learning opportunities by naturally observing how students make use of mobile and wireless and network technologies? 2. How should we assess student learning if we cannot prescript student learning outcomes? 3. How to collect data to capture student learning progression when they are in the "wild" world? 4. How can we develop theories of how student learn in the seamless learning environment? We hope that this research stimulates dialogue among learning sciences researchers on these issues in creating seamless learning environments.

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