The importance of the Learning Sciences for Teaching and Learning through the Internet of Things

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Abstract. The Internet of Things can be a useful tool for teaching STEM subjects using a project based practical approach. However, it creates an added layer of complexity to the process of understanding the learning that occurs and to developing appropriate ways to support both the teaching and learning process. The Learning Sciences has much to offer when it comes to understanding and supporting learning with technology. In particular, the concepts of scaffolding, collaborative learning and context, which are integrated within the Ecology of Resources model of context and associated framework for design and analysis. We use the Ecology of Resources framework to analyse data from a project based learning event involving 14-15 year old students using the Internet of Things. The analysis reveals the different patterns of resource use within and between groups of students and offers some pointers to ways in which this type of learning could be scaffolded.

Keywords: Internet of Things, Scaffolding, Context, Collaboration, STEM

1 Introduction

This paper discusses the importance of the interdisciplinary field of the Learning Sciences to work involving the Internet of Things within an educational setting. In particular, we consider the theoretical and methodological contributions that the Learning Sciences can offer and we report our use of these constructs in the design and analysis of an empirical study of teenage students (aged 14-15 years) using the Internet of Things in their learning about STEM. Our goal in this study is to understand the ways in which the Internet of Things does and could better support the teaching and learning process in project and practice based activities.

The Internet of Things: the network of objects or "things" with embedded computing systems, sensors and network connectivity that can be interconnected with any other network enabled objects or machines, is of increasing interest for education. The Internet of Things exposes the hidden data and communication layer of the Internet to reveal the invisible world around us as data for analysis and use. There is a growing body of research that uses mobile, ubiquitous, tangible and pervasive technology in novel and interesting ways to support learning that is of relevance. For example, in WallCology [1], a range of technologies is used to embed the learners' experiences across a variety of the elements of their physical environment. However, the educational interest in the Internet of Things goes beyond its technologies to engage with the collaborative project based learning that can potentially be fostered by such learning environments and the design of scaffolding to support learning. Both collaborative learning and scaffolding are core territory for the Learning Sciences where there is a substantial body of work that can contribute to our understanding of how to use the Internet of things for teaching and learning [see for example 2, 3]. For the purposes of our research, the Internet of Things created a multidisciplinary learning setting through which we could explore the contextual factors for students. The educational setting created was: (a) collaborative: no one person had the knowledge to complete the project alone; (b) practice and problem-based: no off the shelf solution was used and (c) multidisciplinary: the learning context pushed the boundaries across the subjects.

The Learning Sciences are replete with foundational theory and methods that can inform the educational use of the Internet of Things particularly those that related to Scaffolding, Collaborative Learning and Learning Context. In this paper, we focus on the learning context and discuss the Ecology of Resources [4] as a framework for analysis of the Internet of Things settings.

We report an empirical study with eighteen 14-15 year old students to which we have applied the Ecology of Resources analytical framework and we present our findings. The paper concludes with a reflection on the value of the Learning Sciences, and the Ecology of Resources approach for education using the Internet of Things.

2. The Ecology of Resources framework for analysis and design

The Ecology of Resources offers a model and a framework that can be used to analyse data from teaching and learning interactions and to design scaffolding interventions [4]. It is based upon a particular definition of the term context in which learners are conceptualized as being exposed to "a single context that is their lived experience of the world; a 'phenomenological gestalt' [5]". Context is a reflection of the interactions that learners have experienced with multiple people, artefacts and environments. These interactions create partial descriptions of the world that act as the hooks for interactions in which action and meaning are built, in this sense, meaning is distributed amongst these interactions and interactors [4]

The Ecology of Resources model is illustrated in Figure 1. The resources that are available to the learner embrace a range of categories: the knowledge and skills that are the subject of their learning; the books, pens and paper, technology that are the Tools with which learner interact and People who know more about the knowledge or skill to be learnt than the learner does; and the location and surrounding Environment with which the learner interacts, for example, a school classroom, a park, a virtual world, or a place of work. To support learning, it is necessary to identify and understand the relationships between the different types of resource with which the learner interacts. In addition, it is necessary to explore the manner in which a learner's interactions with these resources is, or might be, constrained: these constraints are identified by the 'Filter' labels in Figure 1. For example, a teacher might filter learners' interactions with the world to focus upon and illustrate a particular concept. The teacher is probably only available during a class, or perhaps at some other times via email, and a learner's access to their environment is mediated by that environment's organization and any rules and conventions that apply to it. Filters can be positive or negative and may also be inter-related. The coherence of the learner's experience can be enhanced through careful consideration of existing relationships between filter elements and between individual resource elements and their associated filters. In addition, it is also important to understand that all of the elements in any Ecology of Resources bring with them a history that defines them, as well as the part they play in the wider cultural and political system. Likewise, the individual at the centre of the Ecology of Resources has their own history of experience that impacts upon their interactions with each of the resources in the Ecology.

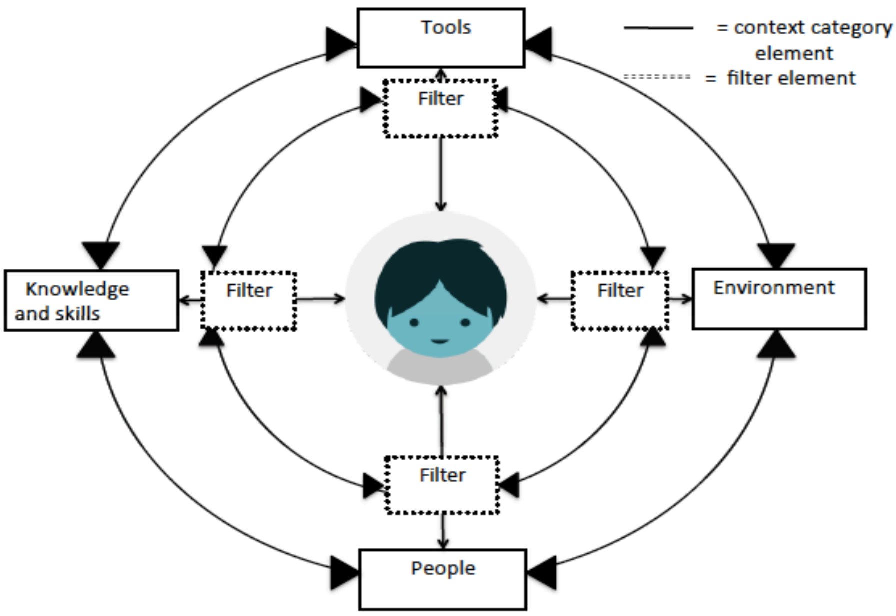

Fig. 1. The Ecology of Resources Model of Context

2 Application of the Ecology of Resources model

The Ecology of Resources model could be viewed statically as merely a snapshot of the set of resources that can be 'optimized' by design and/or by teaching practice. The model can also be viewed as a dynamic process of instigating and maintaining learning interactions in technology-rich environments. The objective of the framework presented here is to support the dynamic process of analyzing and developing technology-rich learning activities involved in Internet of Things settings. The aim of the Ecology of Resources framework is to map out the complexity of learning settings where multiple networked technologies are being used to enhance awareness of the subtleties of a learner's context. The Framework offers a structured process for analysis and/or design that is iterative and has three phases, each of which has several steps.

Phase 1: Create an Ecology of Resources Model using the following steps: *Brainstorm Potential Resources to identify learners'; Specify the Focus of Attention; Categorize Resource Elements; Identify potential Resource Filters; Identify the Learners' Resources; Identify potential More Able Partners (MAPs).*
Phase 2: Identify the relationships within and between the resources produced in Phase 1. Identify the extent to which these relationships meet a learner's needs and how they might be optimized with respect to that learner.
Phase 3: Develop the Scaffolds and Adjustments to support learning and enable the negotiation of the optimal resources for a learner. Phase 3 of the framework is about identifying the possible ways in which the relationships identified in Phase 2 might best be supported or scaffolded. This support might for example be offered through the manner in which technology is introduced, used or designed.

For the purposes of data analysis, which is the focus of this paper, only phases 1 and 2 are needed. A full account of the framework can be found in [4].

3. Education Hack 2015: Working with students and the Internet of Things Participants

An empirical, participatory design-based study was conducted at the start of 2015 involving 18 secondary school students aged 14-15 years. The students had little experience of computer science, but had done some programming in python. None of the students had studied the Internet of Things or embedded systems.

Data Collection and Analysis

A range of data sources were collected: Over 10 hours of video (2 sources for each group of learners, one of the group and one of the laptop screen where programming activity took place), observer notes, audio recordings, email exchanges, phone interviews, and digital capture of discussion and problem solving ideas collected from the school, artefacts, interviews and presentations; surveys and photos. This is a substantial data set and in this paper we focus on the video data from the 2-day hack event. Two researchers coded the video of each group according to the Ecology of Resources framework to identify resources available and in use by the learners and any filters that were in operation. The coding was completed from the perspective of each individual learner in each of the groups. The relationships between the resources and between the learner and the resources was identified and recorded as changes over time. Resource use was recorded at 1 minute intervals. The two researchers discussed all disagreements and reached a consensus.

Results

The students worked in three teams, each had facilitators with a range of skills. Going from an idea to an actual prototype required the students to collaborate, set out tasks and get help from facilitators. Each group worked on a different idea: (1) A glove that controlled home devices (2) A mobile robot to help the blind with navigation and (3) A coin reward system that gave credit to students who collected coins. The data analysis reveals that whilst all learners had a very similar range of resources available to them, their use of these resources was distinctly different both within and across groups. Figure 2 illustrates a summary of the resources used by students at the Hack Fest. It indicates that the most popular resources used where the adults helpers. This was in preference to peers which is surprising given the collaborative nature of the activity. Perhaps a more surprising feature is the popularity of the paper that students used to plan and communicate, and the instructions for the task and the technology. This was surprising given the technical nature of the task, but there was an emphasis on design and this may have accounted for the heavy use of paper. Interestingly the prototype itself was used almost as much as the technology needed to program and connect the different prototype components.

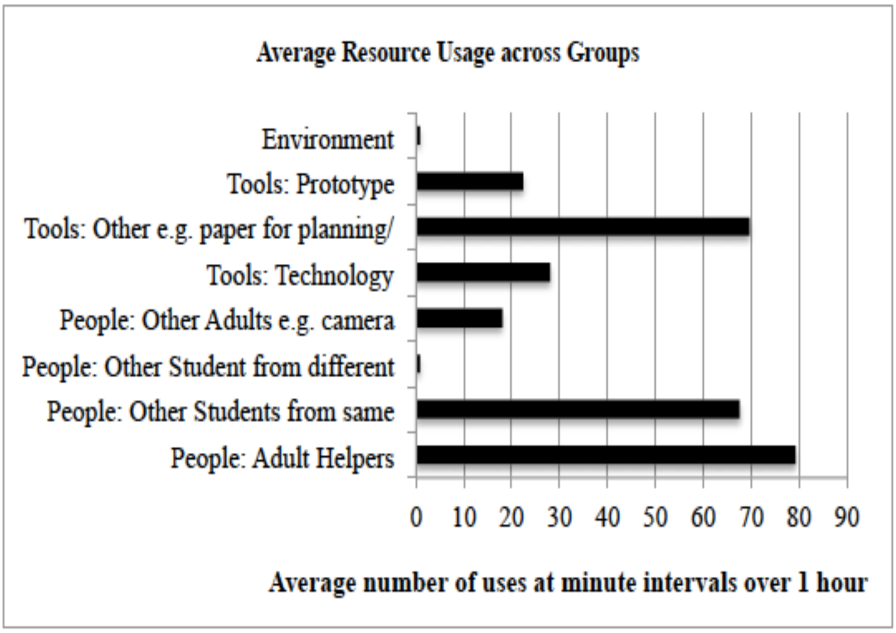

Fig. 2. Summary of the resources used by students at the Hack Fest

Figure 3 compares the resources used by each of the two groups developing the glove and the coin sorted prototype. This illustrates some distinct differences in the resources used by the two groups. The group developing the glove prototype made greater use of the adult resources available and the technology, both laptop and Arduino. They also interacted with the prototype more often. By comparison, the coin sorter used each other and made heavy use of paper and instructions. They used the prototype components, but had not prototype as yet to interact with. These differences between the group use of resources may indicate the different stages in the design process each was at.

If we look at a 1-hour chronology of resource use by a learner in the group developing the smart glove. It illustrates for example, that most commonly several resources are used at the same time. Four resources at the same time is the largest number and most commonly 2 or 3 resources are used together. In addition, there are some groupings of resources that occur more frequently than others. For example, the use of adult help and the laptop; or the use of the prototype with another learner. That might indicate that students collaborated more while they are designing a prototype, whereas, their collaboration was low when they had to use laptop and do coding.

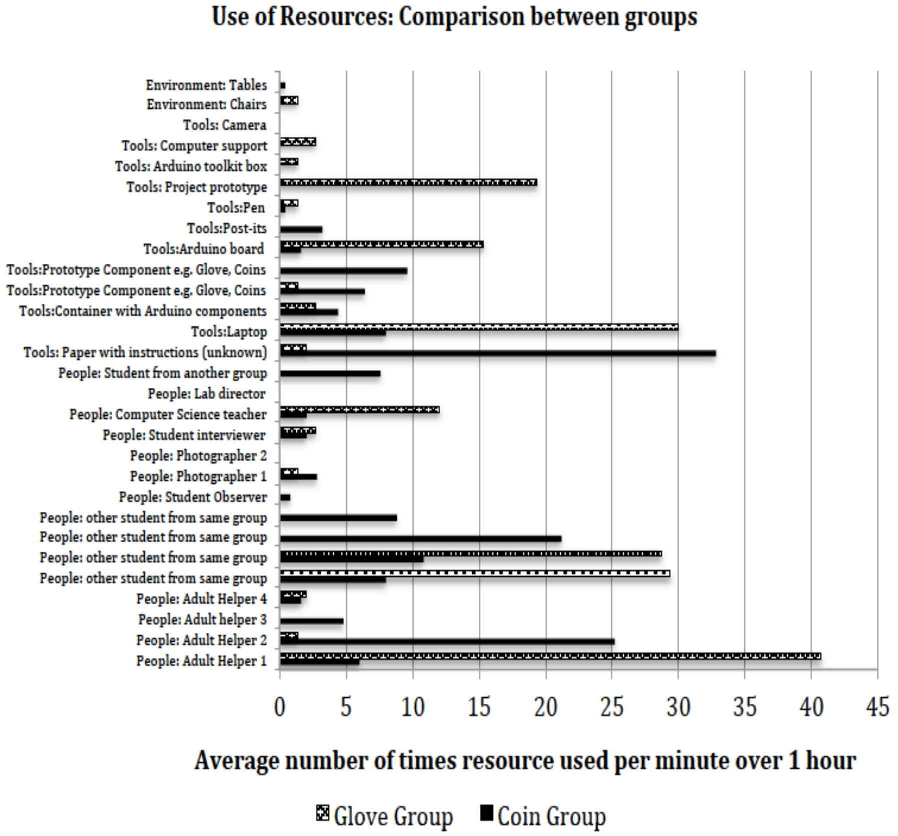

Fig. 3. Comparison of resources used by two groups of students at the Hack Fest

4. Discussion

The use of concepts from the Learning Sciences has enabled us to design and use a methodology for analyzing the data collected during project based practical learning at a Hack Event for teenage learners using the Internet of Things. The Internet of Things enables distributed learning across multiple technologies and contexts. The project based learning activities for which the Internet of Things was used encourages collaboration and problem solving and is well suited to the use of distributed technologies. The use of both the Internet of Things and project based learning demands an analytical methodology that can trace and tap into the learning interactions that occur across and between multiple resources including technologies and people. We need to understand how learners are interacting in these rich contexts if we are to understand how learning takes place and how we can design appropriate scaffolding.

The Ecology of Resources integrates three main concepts from the Learning Sciences: scaffolding, collaboration and context. It offers a framework for the analysis of the complex data that results from tracing interactions in project based learning using the Internet of Things. Our use of the Ecology of Resources has enabled us to illustrate how learners both individually and as groups are using the resources that have been made available to them. There are clear differences in the approaches adopted by learners to resource use and likewise there are areas of similarity. In many ways it is surprising how little learners use the resources available, which suggests that one possible scaffolding approach would be to make learners aware of a wider range of resources.

5. References

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