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Distributed cognition in the middle years: using a forum format to elicit mental models of assessment.

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The project, Mental Models and Robotics and Middle Schooling, was an empirical qualitative study centred within information processing theory and linked with the introspection mediating process tracing paradigm. The study involved students and their teacher in a socio-economically diverse urban primary school and aimed to establish how the identification of participants' mental models can assist in the authentic assessment of learning through a richer understanding of the cognitive development taking place in a technology-based learning experience.

Semi-structured and stimulated recall interviews, questionnaires, teach-back episodes, and teacher and student journals were used to externalise participants' mental models. However, the effect of distributed cognition and the shared understanding of the nature, process, and response to assessment could not be determined by these instruments alone. A videoed forum of the student participants, held subsequent to an assessment episode designed by them, was used to elicit the mental models of assessment from teacher and learner points of view. Results of this forum indicates that middle years students can inform us of their understanding and need for authentic assessment practices that would clearly demonstrate their individual learning journey while adhering to systemic principles.

Introduction

The project, *Mental models and robotics in middle schooling,* aimed to establish how the identification of students' mental models can assist in the authentic assessment of learning through teachers having a better understanding of the cognitive development taking place in a technology-based learning experience. The study followed the participants for eighteen months and aimed to identify the individual mental models and the matches or mismatches that occurred between them throughout the project. It was an empirical qualitative case study of a Year Six class working with robots. The forum used in this study was conducted eight months after the commencement of the robotics learning experiences. It proved to be a rich source of information about the mental models of the middle years student participants and highlighted how their interchange of ideas and thoughts can inform learning and assessment.

Collecting data in the study

Data collected from semi-structured and stimulated recall interviews, questionnaires, teach back episodes and journals were triangulated to ensure confidence that "the data generated are not simply artefacts of one specific method of collection" (Burns, 2000; p. 419). The use of a variety of methods was necessary as the determination of mental models held by participants may be difficult to ascertain. This is because of both their internal, personal nature, and the indirect and problematic nature of measuring internal models (Norman, 1983; Renk, Branch, & Chang, 1994; Staggers & Norcio, 1993). However, mental models are said to be able to be inferred by some form of performance (Jonassen, 1995). This performance may include a user's explanations of a system and their predictions about its performance (Sasse, 1991).

Students' explanations of the robotics system along with their predictions of performance were collected individually using a variety of data collection methods. The focus on the

individual, and in this study how their mental models matched or mismatched the mental models of others, is a norm in cognitive psychology (Banks & Millward, 2000). The situated-cognitive environment (Brown, Collins, & Duguid, 1989) of the robotics laboratory and the pairing of students by the teacher facilitated the sharing of mental models in an authentic learning experience. Students were running and adapting (Rogers, Rutherford, & Bibby, 1992) their mental models as they engaged with others and with the robotics system.

The sharing of mental models of the participants during learning experiences can explain some similarities in their responses to questions on robotics and assessment during the data collection episodes (Rouse, Cannon-Bowers, & Salas, 1992). However, the data collection methods that were used gathered information from an individual perspective. Could the overlap of shared mental models that were evident in the learning experiences be replicated in a data collection situation that involved all of the student participants? Using a similar context (Cannon-Bowers, Salas, & Converse, 1990, 1993) to the learning experience for the collection of data may uncover more information about how the students distribute their understanding of robotics and how they are assessed.

A decision was made to structure an assessment activity that involved the four student participants. Each student was to design a 30-minute activity for one of the other participants that would provide them with the opportunity to show what they have learned about robotics. Two sessions were held in one hour-long period and all interactions were videotaped. The following day the four participants took part in a forum with the author where the events of the day before were discussed. The aim of the forum was to have a semi-structured exchange in order to investigate their mental models and the distributed cognition of those models.

Why mental models?

Craik (1943) first posited the theory of mental models in his paper, "Nature of Explanation", when he proposed that a user's mental model was either a dynamic representation of reality, or of the model of the system created by the designer. Johnson-Laird (1983) continued the research using a more theoretical approach in text comprehension and reasoning, proposing that mental models exist in order to understand the phenomena which they represent in the real world. Norman (1983) used a more interdisciplinary approach and suggested that mental models instantiate the structural relationship between objects and events thus allowing the user to plan actions, explain, and predict external events.

It is the functionality of the manipulative nature of mental models in cognitive development (Norman, 1983) and the facilitation of the investigation of alternatives during the learner's exploration of the problem (Carley & Palmquist, 1992; Renk, Branch, & Chang, 1994) that is of interest in this study. The students were being exposed to a new learning environment for which they would apply previous knowledge to unknown artefacts: robots and their programming system. Their evolving mental models should guide their interactions, enable them to evaluate expected events and interpret any unexpected events (Norman, 1983).

Papert (1980) documented an experiential approach to learning with computer-based discovery learning. Since then there have been several studies (e.g., Barchi, Cagliari & Giacopini, 2002; Kiesler & Goetz, 2002; Resnick, 1989; 1994) that have aimed to establish the cognitive development and mental model construction of children who learn within contexts that involve technological objects, such as robots. The methodology of building, testing, evaluating, and altering a robot's behaviour requires an "experimentally driven design" approach by the students

(Bilotta & Pantano, 2000, p. iii). This approach enables the students to activate and adapt their mental models to build and program a robot to achieve a predetermined goal.

Resnick (1989; 1994) discovered that different solutions in programming the robot to accomplish goals were created by the students particularly where the tasks the robots were to accomplish were complex. Mental models that were not viable needed to be improved in order for the robot to be programmed successfully (see Norman, 1983; Seel, 2001). Of interest in this learning situation is the students' building and programming of the robots: a process that can transform learning for students who actually do something with the knowledge they gain thus making the act of learning more self-directed (Papert, 1980). The authentic assessment of self-directed learning is a challenge. The 'get it right/get it wrong' paradigm (Papert, 1980) may not provide an accurate picture of the cognitive journey undertaken by students. An opportunity to determine how they distribute their understanding of assessment may provide valuable information on their shared mental models of learning with robotics.

What the forum added

The forum provided a rich source of data. The first fifteen minutes saw the participants responding individually, without much discussion, to the questions put to them. This author was well known to the students and their hesitancy to interact with each other could not be attributed to their reticence to share their thoughts with someone they did not know and trust. The context was new and it took some time for them to adjust to its novelty but it allowed them the opportunity to express and explain their thoughts. Persistence was rewarded and the interactions grew richer, culminating in a 'we-ness' or 'us' collegiality of shared mental models (Anderson et al., 1996) that was relative to the social context (Bibby, 1992) of the semi-structured exchange.

The following section of this paper reports how the students' reactions evolved from an individual recount into a shared mental model discourse. Some insertions have been made in parentheses to assist clarity and fluency. The author has emphasised some words in bold to illustrate the theme being developed by the group.

The participants were asked to reflect on the assessment tasks they had designed for each other the previous day. Their responses to the question, *"Was your assessment task a good way to assess robotics?"* are shown below.

Bree	*Not really.*
Jayne	*No. I'd like more time.*
Bree	*More time.*
Interviewer	*Why more time?*
Jayne	[To show] *how good you are at making a robot. How much work you put into it.*
Interviewer	*How could you show that?*
Jayne	*By building it at your best and taking more time to see that it's good.*
Ellen	… [we should be] *assessed over a few weeks because one day you might not be caught doing too well and the next day, after it, if you were tested on that day … you might do the best you've ever done.*
Bree	*Or you might have thought about it that night.*

Interviewer	*So is reflecting over what you're doing and having lots of opportunities to show it the best way?*
Ellen	*Yes ... you might learn something in the first lesson and then you can show it in the second lesson.*

A shared mental model of assessment that explains why conducting assessment over time best shows students' capabilities is being built between the members of the group. This information would have been difficult to obtain through individual interviews as the students were not just offering their personal mental model but were adopting a non-threatening communication practice (Rogers & Ellis, 1994) to build a picture that represented their shared mental model of assessment. Assessment practices, as they occur in the classroom and are declared in curriculum documents, are under the spotlight in Australia. Traditional methods rarely allow for the integration of assessment into the learning process which enables authentic assessment by students and teachers (Stables, 1992). The integrative nature of robotics also calls for a more holistic approach to assessment in technology. This holistic approach to learning (Kimbell et al., 1991) enables students to transfer what they know to the performance of tasks (Cook & Rowe, 1998).

As the forum progressed, it proved to be an effective instrument to collect rich data on shared mental models. Bree becomes the catalyst for each new discussion, although her comments are brief. She is, as a catalyst, enhancing the coordinated performance of the team although here we are not operating in a tank simulator (Minionis, 1995 in Banks & Millward, 2000) but in a discussion forum. The students had provided help, in some form, to each other while being assessed. The question asked was *"How much help is too much?"* The responses were:

Bree	*A little.*
Jayne	*A little bit of advice.*
Bree	*If they were struggling you could help them, but not actually tell them what it was.*
Ellen	*Don't give them the answer. Give them clues on how to get the answer.*
Jayne	*Yeah.*
Sam	*Say you've done something wrong there and let them check it out.*
Interviewer	*So how much help is too much?*
Bree	*Actually giving them the answer.*
Jayne	*Or building it for them.*
Bree	*Yeah.*
Jayne	*Doing the computer program for them as well.*
Bree	*Giving it to them.*

The students' mental models of two systems were being discussed during the forum. The first system, robotics, was the context in which the second system, assessment, was situated. The mental models for both were being run in parallel by the students in their reflection on the 'help' question. It is interesting to note that their understanding of how the assessment system works is not a uni-dimensional structure but reflects an understanding of what the system contains, how it works and why it may work the way that it does (Carroll & Olsen, 1988).

The students had 'run' their mental models of assessment the day before from two points of view – the assessor and the assessed. Now they were able to distribute the mental models they

had of learning and the assessment of learning with other members of the forum. The transcript shows that while they may have been coordinating their responses, they were not merely repeating statements made by others in the forum. Here a shared mental model of assessment was being run collectively through the 'propagation of representational states' (Banks & Millward, 2000, p. 4), in this case a verbal reporting of their experiences and understandings.

To gain more data on their shared mental models of assessment, the students were asked, *"What can you do to show the teacher what you've learned?"* Their responses were:

Bree	*Being able to **write** about it.*	
Sam	*Yep, that was what I was going to say!*	
Interviewer	*Where would you write about it?*	
Sam	*In your **journal**.*	} simultaneous
Ellen	*Your journal.*	
Sam	*If you were asked a question about it and you didn't know what it was then you probably haven't done it.*	
Interviewer	*So even though robotics is physical, to show success as a learner would mean that you would be able to write about it?*	
Sam	*Yep.*	
Bree	*Or **tell** someone about it.*	
Sam	*Or **show**.*	
Ellen	*Like, show them you're **happy**.*	
Bree	*Show them a **picture**.*	
Sam	*Show **what** you've **done**.*	
Jayne	*Showing **how** you've **done** it.*	
Bree	*Show how you **feel**.*	
Sam	*It would show **all** of it.*	

The students were bouncing their ideas off each other and becoming quite excited as the shared mental model of assessment developed through this series of responses. The transcript shows that they were becoming collaborative meaning-makers because they were responding as a group that has experienced common practices of assessment (Jonassen & Land, 2000). As a group they moved from '*write*' to '*tell'* to '*show'* including showing '*what you've done'*, '*how you've done it'* and *'how you feel'*. The importance of emotions as an indicator of success in learning was clearly evident with responses from two students for the inclusion of showing how you feel and that *'you're happy'*. One discussion in the forum centred on the inclusion of graphs to show a continuum of skills and knowledge with all of the students referring to the need to include a *'confidence'* scale. The idea of confident, happy learners was of importance to the group and reflects their shared mental model of the demonstration of learning.

The question, *What can you do to show the teacher what you've learned?* was asked again in a different format later in the forum to determine whether the students' previous responses were reliable. It also provided an opportunity for them to more fully develop the idea of assessment. These responses, initiated once again by Bree, contain more detail:

Bree	*Show the teacher you can write it down.*
Interviewer	*What would you show the teacher?*
Bree	*Ask her to get you to build a robot and try to be able to do it.*

Jayne	*You could build a robot, pick a program on the computer and download it, so she can see what you've learned.*
Interviewer	*Do you think she'd do the* ***same for everyone****?*
Bree	*(Negative head shake)*
Ellen	*No because we might have* ***different abilities****. Some might have more turns* [goes] *than other people.*
Interviewer	*So that's okay?*
Bree	*Yes, because people have* ***different strengths****.*
Ellen	*Like* ***some people like it better*** *than us three would.*
Interviewer	*So that's the way you would like to be assessed?*
Bree	*Yes.*

This section shows that the students acknowledged how different tasks for assessment may suit different students due to ability, strengths, and interest. They have built a powerful picture. The shared mental model of individual capabilities and the way that these can be identified by the teacher to enable authentic assessment were further developed as the discussion continued with how this could be done as indicated below.

Sam	*I might keep* ***photos****. Show them to the assessor.*
Interviewer	*From one day or over a period of time?*
Sam	*Could be both.*
Ellen	*Yeah, if you* ***like use pictures to record*** *the first idea you have from the start and keep them at the end and the teacher can see how much you've learned from them.*
Sam	*Recently I made a* ***portfolio*** *because I had to go for an interview at my new school and I had to show the principal what I've done.*
Interviewer	*Would that be a good assessment for robotics?*
Ellen	*Yes.*
Sam	*Yes,* ***type it up and put them in****.*
Jayne	*Take a* ***photo of the robot*** *that you built.*
Interviewer	*So your assessment could be run by whom?*
Bree	***Us!***

Sam had experienced creating a digital portfolio of work because he had attended an interview at another school where evidence of this work was required. Ellen used his report of *'photos'* to develop the idea of recording early attempts at robotics before Sam discussed his portfolio of work. They were building a shared mental model of assessment that excluded the actual artefact, '*the robot'*, and replaced it with the artefact, *'the portfolio'* that would best indicate to the teacher what they had learned. While Bree had been the catalyst for much of the discussion, she also made closing comments that succinctly summarised the preceding discussion. Her conclusive comment *'us'* when asked who would run the assessment in robotics indicated a mental model of assessment that showed how a novel shared concept may be organised through communication, in this case the forum, and provide a basic mechanism for the social construction of knowledge (Berger & Luckman, 1967).

In summary

This method of data collection for mental models provided rich results to supplement data collected by more traditional methods. It highlighted how middle years students can communicate cohesively within a group in response to questions about an experience and their shared mental models of robotics and assessment. It informs us of the ability of students to contribute to their own assessment in ways that make sense to them and realistically show who they are as learners. In fact, they communicate a real need to be involved; to be a part of the 'us' collegiality where how happy you are with your experiences and the confidence you exhibit in reaching your goal is as important as *'what you've done'* and *'how you've done it'*. The implications for classroom teachers are substantial. While much effort is made to individualise programs for independent learning, one might ask how much effort is similarly invested in individualising assessment. The implications are that time should be invested in involving students in their own assessment; particularly in areas of technology where integration of many curriculum areas provide rich experiences for students. Student commitment to their own learning can be enhanced if they are afforded shared responsibility for showing what they have learned.

The use of a forum methodology demonstrates significantly the interdependencies amongst individual's mental models of learning and assessment. It highlights the fact that distributed cognition is not limited to learning situations but is also relevant to data collection instruments for researchers working with middle years students.

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