Capturing evidence of metacognitive awareness of pre-service STEM educators' using 'codifying' of thinking through eportfolios (Research-to-Practice) – Strand: Other

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Introduction

It is widely understood by STEM educators and policy makers that there is a need for students to be able to show evidence of higher order thinking and self-regulated learning[1]. To demonstrate the ability to work autonomously students must be able to display and communicate the ability to self-audit and self-regulate their thinking[2]. One aspect of self-regulated learning is metacognitive awareness. Metacognitive awareness is defined by Tarricone as awareness of the learning process, reflection on learning and memory, identification of strategies for problem solving, and monitoring and control of learning processes[3]. The importance of fostering and developing student's ability not just to reflect on their thinking but to become aware of and critically examine the evidence of their thinking that they are producing is an important aspect of metacognitive development. This raises the question how do engineering educators observe that students are capturing evidence of metacognitive awareness during the design process?

This paper explores the implications of a codifying system used through e-portfolios to identify students' metacognitive awareness during a design task. The use of e-portfolios helps students to manage their own learning as it allows them to collect, reflect and present their learning[4]. A technology supported learning environment allows for a greater scope and more convenient means for students to monitor and control their learning throughout the iterative design process which students experienced during this study. During this design project students were asked to codify their thinking into three categories (explained in next section) which prompted them to become aware of their thinking and evaluate the type of evidence they were producing in their eportfolio.

Metacognition

John Flavell [5], explored the concept of metacognition through various studies, defining it as *"one's knowledge concerning one's own cognitive processes and products or anything related to them."* Flavell investigated if children were aware of understanding some component of their memory and cognition[6]. The findings from this research provide evidence that children possessed the capability to reflect on their own thinking. After this research, Flavell defined metacognition as information and cognition about the cognitive processes and conceptualised it as the learner's information about his or her own cognition[6]. The work of Flavell[6] splits metacognition into two concepts, metacognitive knowledge and metacognitive regulation. Metacognitive knowledge can be described as knowing that you know something or being aware of your thoughts. Metacognitive regulation also known as metacognitive strategies are processes a person carries out to ensure a cognitive goal by

controlling cognitive activities[7]. Other authors have also defined metacognition similar to Flavell. Swanson[8] defines metacognition as individuals' awareness of their ability to monitor, regulate and control their own activities concerning learning. Metacognition generally means higher level thinking about how a learning task will be handled, and making plans on processes of observing and evaluating comprehension[9]. This was the one of the important aspect of the project in this study to see if student were aware and could handle their thinking. Wilson[10] regards metacognition as knowledge and awareness of thinking processes and strategies (together with the ability to evaluate and organize these processes). Brown[7] conducted many studies after Flavell on the comprehension of information or the problems related to the understanding of information or the use of information when a clear definition has been given. Metacognition can be explained as individuals' use of information while they are learning or fulfilling a task and a deliberate organization in cognitive processes. There are a few variations on the definition of metacognition, it is the belief of the author that it can be to some extent left open to the individual's interpretation. As Schunk[11] recommends there is a need to provide clearer definitions of metacognition and self-regulation of learning. Especially in STEM education there is a need to define what it means to allow for the fostering and development of metacognitive abilities.

Metacognitive Awareness

Derived from metacognition is metacognitive awareness. Hargrove has shown that development of metacognitive awareness can help in creative problem solving. So as outlined earlier it is up to the educators to facilitate the capture of students metacognitive awareness which is defined by Tarricone as awareness of learning process, reflection on learning and memory, identification of strategies for problem solving, and monitoring and control of learning processes[3] The capturing of students metacognitive awareness will be explored in the next paragraph.

Whitebread and Coltman conducted observational studies of young children's, (aged 3-5 years old), metacognitive and self-regulatory abilities[12]. The children were engaged in mathematical activities designed by practitioners to facilitate metacognitive processes. Metacognitive 'events' were identified and the children's behaviour was analysed for indications of metacognitive thinking. At the same time, the pedagogical context of the activities, including interventions by adult practitioners, was analysed in relation to the metacognitive opportunities afforded. They found when tasks are placed in contexts which make sense to young children, they can demonstrate clear signs of emergent metacognitive and self-regulatory skills. Whitebread and Coltman considered the development of a coding framework identifying verbal and non-verbal indicators for metacognitive and self-regulatory behaviour[13]. The construction of an observational instrument, the Children's Independent Learning Development (CHILD 3–5) checklist, is also reported together with evidence of the reliability with which it can be used by classroom teachers and early indications of its external validity as a measure of metacognition and self-regulation in young children. Given the educational significance of children's development of metacognitive and self-regulatory skills, it is argued that the development of such an instrument is potentially highly beneficial. Robson[14] concludes that students must be afforded the right opportunity to express what they

were thinking when they were engaged in a task and some students, while capable of performing metacognitive skills, were unable to articulate their actions.

While there is literature presented on how to capture metacognitive processes through observational techniques, no evidence was found of methods to capture evidence of metacognitive awareness without the use of these labour intensive techniques. It is hard for teachers to continually observe individual students in order to capture every cue in their behaviour or speech. Educational tools such as an electronic portfolio (eportfolio) which afford the opportunity to capture this while it is happening have great potential from an assessment perspective[15],[16]. With a large class of freshman students it would be difficult to capture all their metacognitive actions through observation techniques so the use of a coding system, which "tagged" an individual's cognition, was employed to see if evidence of students' metacognitive awareness could be captured through eportfolios.

Method

Approach

This was an exploratory study designed to examine the impact of a codifying system that students used to colour code their thinking through an eportfolio. The codifying of students evidence in their eportfolio was employed to explore if their metacognitive awareness could be captured and identified which occurs during the iterative design process. This eportfolio was created concurrently with a design artefact as to fulfil an open ended design brief during a twelve week semester. This was part of a module which took place in the second semester of year 1 in a four year Initial Technology Teacher Education degree programme. The module of study was a materials processing module where students develop values and appreciation for metal and wood craft skills through an open ended design task while building a construct of what it means to be capable in these disciplines.

The design project

The students were given the following design brief: Students were asked *to design and make a flower that conveyed an emotion and create a scene that reflected that emotion.* Work was documented during the process and students were instructed to present evidence of their learning during the design process through an e-portfolio using student-defined criterion. The timeline of the project is shown in Table 1 below.

Table 1: Timeline of Project

Week	Workshop Activity
Week 2-5	Students engage in 4 activities that develop the necessary skills and knowledge for the design project. Material processing, material selection, etc.
Week 5-12	Students design and realise decorative design projects and complete an e-portfolio in tandem. The e-portfolio and artefact were presented for assessment at the end of the module.

The portfolios were assessed using a democratic assessment process called Adaptive Comparative Judgements (See references [17,18]) . This is democratic peer assessment instrument based on Thurstone's law of comparative judgment. This method produced a rank (Figure 1) of the student portfolios then a sample of these portfolios was taken for analysis.
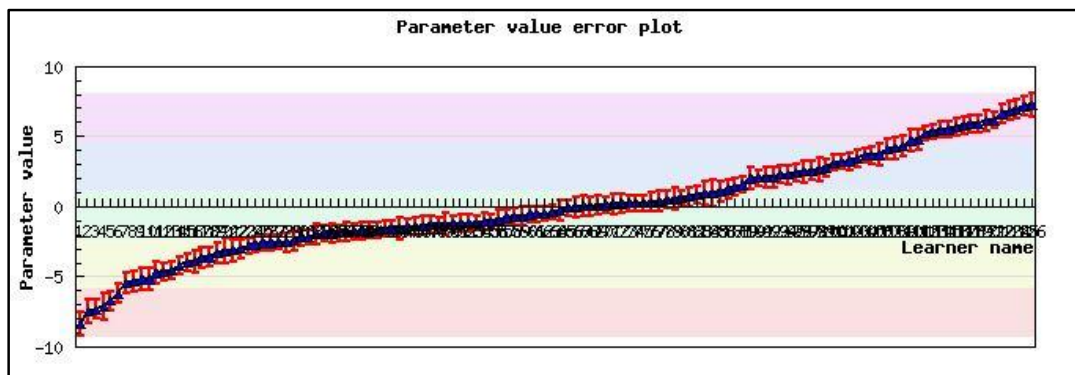

Figure 1: Rank of Student ePortfolios after the democratic judgement session

Participants

The participants (n=125) were 1st year students (freshmen) of a four year Initial Technology Teacher Education degree programme. Each participant would have varying degrees of experience when it comes to workshop skills and knowledge including materials processing, machine skills and hand craft skills. They would also have varying degrees of education as some would be CAO entrants (come directly from secondary school) and others would be mature student entrants (over 23 years of age) with various trade and industry backgrounds.

Design

The students were asked to create an eportfolio using student-defined criteria. The electronic nature of the portfolio allowed students to represent evidence of their learning through a

broad set of media, and this evidence of learning was determined by the student on an individual basis. Students made a decision on what to present as evidence of their learning which they experienced throughout the design project and the decisions they made were based on their construct of capability in STEM based practical subjects. The amount of panes (Figure 2) a student used in a portfolio was determined by the individual student and they also gave a title or heading to that pane. This meant that the content of the portfolio was completely left open to the students.
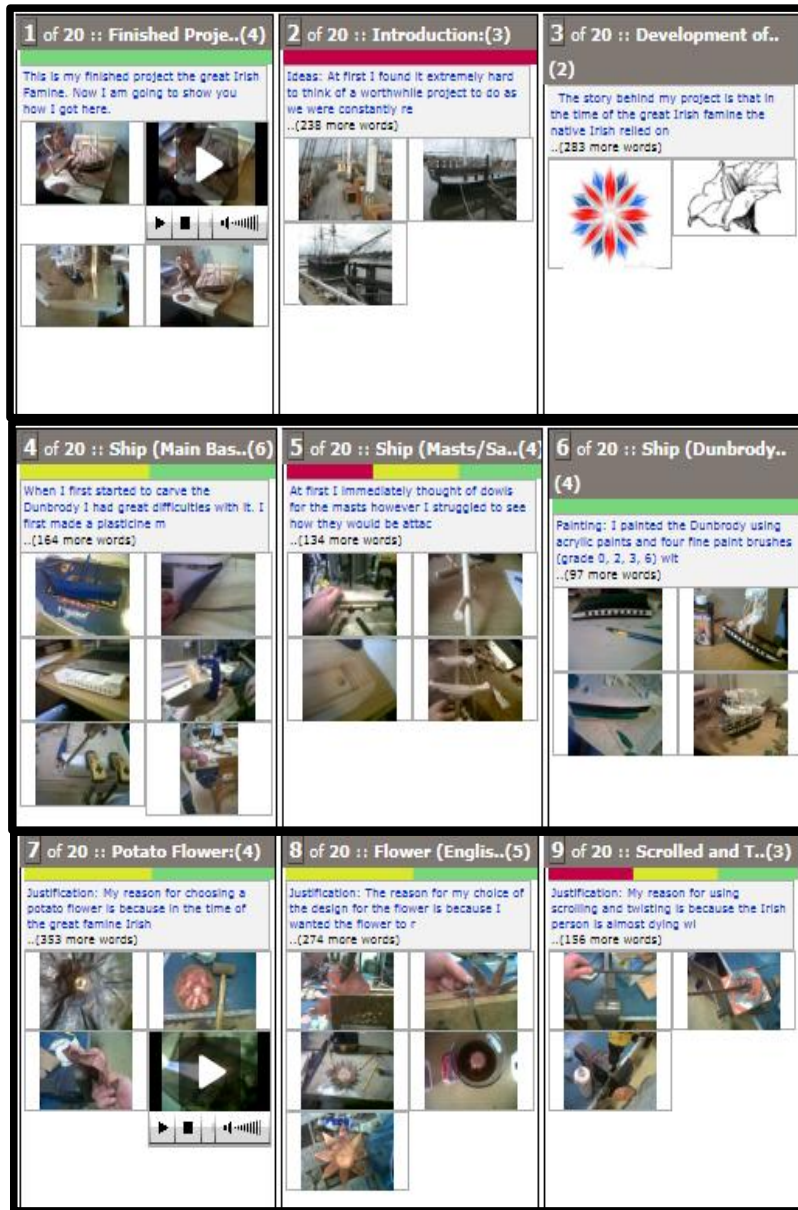

Figure 2: Example of student e-portfolio with colour codification on each individual pane.

The students were asked to tag each pane with at least one of the following codifications in the table below (Table 1) but this was not mandatory. If a student decided they could leave their pane blank without a colour codification. Each pane would contain some form of media about a certain aspect of their project e.g. sketches, photos, text, etc. The purpose of the

codification was for students to identify and become aware of their learning process particularly when they solve a variety of problems throughout the design learning process and that their instances of innovative thinking were not overlooked.

Table 1: Explanation of Codification of panes in the portfolio

Colour	Meaning	Explanation
Red	Having	This is an instance of a student identifying an idea
Yellow	Growing	This is an instance of a student developing that idea
Green	Proving	This is an instance of a student providing a solution to a particular problem they encountered / proving an idea

Implementation

These portfolios were peer assessed and the rank represented what the democratic consensus of the student cohort. As this was an experimental study, with a lot of portfolios, two were chosen from the top, middle and bottom of the rank. This was to explore if there was any trends emerging amongst performance in the rank and evidence of metacognitive awareness. The task of analysing the entire cohort of students' portfolios was not achievable within the timeframe for this paper. For the six portfolios that were analysed, each pane of that portfolio was quantified and the codifications of each pane were also counted. The qualitative data that accompanied each individual pane was used to qualify the reason for codifying each piece of evidence. An analysis of the discourse took place to interpret the qualitative data. The subjective nature of the evidence presented had to be interpreted for meaning so this was done by a single researcher who is a subject expert in STEM education. The single researcher ensured that there would not be any discrepancies' between interpretations. The results of the analysis will be shown in the next section.

Findings

As it was outlined in the previous section it was not mandatory for students to use the codification system to identify when a student was *"having, growing or proving"* ideas during their design project. In the sample shown below (Table 2) all but one participant used the codification of panes to varying degrees.

Table 2: Percentage of portfolio panes tagged by selected participants

Participant	Number of panes in eportfolio	Number of panes codified	% of panes codified	Number of panes with more than one codifier	% of panes with more than one codifier
1	15	13	87	10	67
2	19	19	100	14	74
3	11	10	91	4	36
4	11	10	91	8	73
5	11	11	100	5	45
6	6	0	0	0	0

For Participant 1, 87% of the panes in the e-portfolio were codified with 67% of the panes containing at least two codifiers, *"having, growing or proving."* Participant 1 showed some evidence of their metacognitive awareness through various comments about their experience by reflecting on their learning process,

> *I created models of my project and the different aspects of it, so as I could help myself visualise what I was attempting to do and see how it would look.*

Participant 1 also showed an awareness of need to implement an appropriate problem solving strategy when stating, *"so to solve this problem I had to keep....."*

For Participant 2, 100% of the panes were codified with 74% having at last two or more codifications. Examination of the qualitative data showed examples of reflection and awareness with comments such as *"I decided, I realised, I had to come up with another idea....."*

For Participant 3, 91% of the panes were codified with 36% having at last two or more codifications. There was evidence that this participant was aware of their thinking and clearly solving issues that were encountered,

> *"where I encountered my first problem.......here is some of my ideas"*

The participant also showed evidence that he was aware of their learning process,

> *"Here I am showing how the background was put together and how it tells the story behind the whole project"*

For Participant 4, 91% of the panes were codified with 73% having at last two or more codifications. This participant demonstrated an awareness of what he had learned and experienced and application of prior knowledge,

"in the end I didn't want to ruin the finish on it so I left it as it was........."

They continuously showed evidence of reflection with descriptive commentary beginning sentences with; *"I felt, I decided on....."*

For Participant 5, 100% of the panes were codified with 45% having at last two or more codifications. The codification of the panes prompted the realisation which forced the participant to reflect on their thinking during the design process;

> *"I had all my ideas in my head and none on paper so naturally that was my next step. I drew sketches and created a model......."*

For Participant 6, 0% of the panes were codified with 0% having at last two or more codifications. With the lack of codification from participant 6 there was no sign of any meaningful reflection or awareness of thinking in this e-portfolio.

Discussion

Being mindful that this is quite a small sample of the entire cohort of students, there was no indication that more or less coding of the eportfolio impacted on the position a student's finished on the rank. There may be merit to investigating further if there is a correlation between the instances of "reflection on learning and memory" and performance in the rank. This may have had an impact on the quality of the artefact produced during the design process. A statistical analysis using a larger sample may be needed in this case.

From the data, what was evident in the portfolios was the level of narration from participants. They used each pane to delicately tell a story of their experience throughout the design project and one thing that was evident was that the students who performed at the top of the rank narrated the story of their project clearly and concisely. While narration is not directly related to metacognition there were examples of students reflecting on their learning and memory. This is a sub element of metacognitive awareness, and could suggest that codifying may have an impact on the amount of occurrences in which they become aware of what they have learned. Descriptors used by Whitebread and Coltman[13] in their observational studies on the capture of metacognition suggest that a student narrating their thinking is considered evidence of metacognitive behaviour.

The electronic portfolio produced by the student had a dual purpose. The e-portfolio was a reflective dialogue for the student but it was also a presentation of what they had learned. The very nature of having to refine their thoughts on the design process and present these thoughts for assessment was an example of self-regulation of learning. But also they were forced to think more critically about the content of the portfolio as they had to be explicit about whether they were *"having, growing or proving"* ideas. The level of internal dialogue that took place must have been high in some cases but not in others. There is no definitive way of quantifying this but it is evident that it happened. The nature of metacognitive regulation is self-reflective and critical reflection of one's learning experience as outlined in

the literature. The introduction of a codification system like the one used in this study initiated some degree of monitoring and control for the participants which is an element of metacognitive awareness. The purpose of this was to capture innovative thinking and in a way it acted as an external regulator or the "other regulator", which Vygotsky[13] describes as the presences of 'others' as a regulator of a person's cognition. In this case the "other regulator" was not a person but the regulator was similar to the role a teacher would play in the process. The "other regulator" could help instil good practice of reflecting on their own learning process and in time the behaviour could become more entrenched, making monitoring and control of their cognition the natural instinct of a STEM student.

To conclude, the use of coding of thinking similar to what was used in this instance may be a transferable concept to secondary and primary STEM subjects provided the design and implementation suits the cohort. As Schunk[11] recommends the assessment of metacognition should reflect the processes being developed and this is important to ensuring alignment between intended outcomes for STEM students and assessment instruments. Further to this, issues that may need to be considered include;

- Establishing the relationship between performance and metacognitive awareness in the design learning process.
- The pedagogical implications of using codification system of students thinking.
- Development of a rubric to identify authentic evidence of metacognition in STEM based design learning?

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