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## **Narrative pedagogies in Science, Mathematics and Technology**

**Abstract** Despite years of research there remains serious concern regarding the engagement of students in science, mathematics and technology education. In this paper the authors explore how narrative pedagogies are used in science, mathematics and technology in order to make the subjects meaningful. The paper focuses specifically on the role and aesthetic nature of narrative as a pedagogical approach in these school subjects and between school sectors. Case study methodology was used to compare the findings of two independent studies investigating the role of narrative-based pedagogies in mathematics and science (first author) and technology (second author). Based on this comparison, this paper proposes two perspectives on narrative-based pedagogies that deal with the connection of students with the subject: inward-looking that situated the learner within the story generated around artefact creation, and outward-looking that situated the stories of the content into students' lifeworlds. The use of this comparative lens enabled a higher level of analysis that could not have been achieved by each research program, generating a broader narrative that provided deeper insight into the teaching and learning experience.

**Key words** Aesthetics, education, mathematics, narrative, science, technology

This paper responds to concerns related to the dis-connect between the content or methodologies on offer in mathematics, science and technology, and what might be considered relevant to students' current and future lives (see, for example, Tytler, 2007), by proposing a pedagogical framework that builds connections within and beyond the subject through narrative,

or story. The paper draws on an aesthetic framework to compare the nature and purpose of these connections across mathematics, science and technology.

Narrative-based pedagogies have the potential to evoke a personal response in the learner, a response that is aesthetic in nature, meaning that a value judgement is placed on the experience by the learner. Bruner (2002) acknowledged the role of the narrative in writing oneself. Boström (2006) draws heavily on Bruner's work to research the role of narratives in learning and teaching chemistry, emphasizing that "we create ourselves through the art of narration. Mankind is constructed and reshaped in the form of narratives explaining who I am and what I should be" (Boström, 2006, p. 48). Stories that learners and teachers tell reflect something about themselves, and themselves in relation to the subject. As Kerby (1991) states, a sense of self is generated through stories. Elbaz-Luwisch (2002), for example, speaks of the practice of teaching as being constructed when teachers tell and live out particular stories. We construct our identities by constructing a narrative around what we believe, value, know, think, and can do. Therefore, coming to understand the nature of the narrative-based pedagogies proposed in this paper requires appreciating the aesthetic dimension of learning, for emotion and cognition are inextricably linked in the process of student learning (Zembylas, 2005). We draw on a Deweyan lens to make this link.

We argue that narrative-based pedagogies provide for students opportunities to learn through "aesthetic experience" (Dewey, 1934/1980) as they build narratives about, and through, their learning, and as they construct narratives from their lived experiences. Milne (1998) argues that narratives "help students organize their knowledge into explanatory frameworks which serve them as interpretive lenses through which to comprehend their experiences" (Milne, 1998, p.178). Dewey's notion of "aesthetic experience" signifies "experience as appreciative,

perceiving and enjoying” (Dewey, 1934/1980, p. 47). According to Dewey, current experiences provide parameters and expectations for future experiences. The cognitive is continuous with the affective, and the experience is part of a continuum of experiences. Narrative frameworks have the potential to promote such experiences because of the personal investment involved in creating narratives around personal experiences. Acknowledging the aesthetic dimension of these narrative experiences provides a way of exploring the connections between what teachers and students know about the subject and its content, and their personal response to that knowledge.

Further, and in keeping with Bruner’s ideas, Dewey states that a person is transformed by what they have experienced and what they have come to know out of that experience. “Knowing changes the individual as well as the individual’s world” (Girod, Rau & Schepige, 2003, p. 578). The transformative nature of aesthetic understanding can lead to identity formation and personal positioning. A person can say “I am the type of person that looks at the world in this way”.

The framework of “aesthetic understanding” from Girod et al. (2003) is useful when describing this personal response: “Aesthetic understanding is a rich network of conceptual knowledge combined with a deep appreciation for the beauty and power of ideas that literally transform one’s experiences and perceptions of the world” (p. 578). Girod et al. (2003) draw from Dewey’s epistemology to describe aesthetic understanding as being “compelling and dramatic”, “unifying”, and “transformative” (p. 578).

Various research have reported on the role of the aesthetic in the activity, psychology and affective response of scientists and mathematicians to their discipline (Root-Bernstein, 1989; Tauber, 1996), often with the intent of informing mathematics and science teaching of that which provokes an aesthetic response (Burton, 2002, 2004; Sinclair, 2004; Wickman, 2006). In mathematics, for example, Sinclair (2004) explains that aesthetics has long been claimed to play

a central role in developing and appreciating mathematics. Recognition of the beauty of mathematics stems from the Ancient Greeks who believed in the affinity between mathematics and beauty based on its order, symmetry, harmony and elegance. This is often called the aesthetic of mathematics. This aesthetic is often removed from the mathematics curriculum (Doxiadis, 2003) and the mathematics story is often shortened to a sequence of steps that can result in students failing to experience the pleasure of the process (Gadanidis & Hoogland, 2002).

In science also, the words beauty, inspiring, artful and passion are often used by scientists to describe their work (Girod et al., 2003). “The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful...intellectual beauty is what makes intelligence sure and strong” (Poincare, 1946, quoted in Girod et al., 2003, p. 575).

Lewis (2005) also identifies technology education as being a subject in which “aesthetics and creative performance are critical curricular dimensions” (p.35), requiring an approach that focuses not on “knowledge for its own sake” (p.46), but on thought that leads to creative expression. Aesthetics and the need for students to develop an aesthetic appreciation is an important element of technology that is widely acknowledged in the literature (See, for example, Christiaans & Venselaar, 2005; Jones, 2003; Pavlova, 2008). We would argue that a teacher that is aware of the aesthetic dimensions of experiencing the world has the potential to situate the learner into the story of the subject.

In this paper we use multiple case study methodology to explore the nature of what appear to be subject-specific differences in approaches to the use of narrative based pedagogies, focusing specifically on their aesthetic dimensions. In describing how narrative can be used to

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enhance teaching and learning, it is important to understand how the subjects play a role in determining pedagogy. As with all disciplines, mathematics, science and technology are distinctive in terms of moves, genres, syntax and content, the mastery of which takes time (Gardner, 2004). They are distinguishable epistemologically and methodologically, and these differences are represented in the subject matter, pedagogies and purposes associated with their respective school versions (Author, 2010 – published book). We were interested in exploring the purposes associated with, and the nature of, narrative based pedagogies some teachers used to make their subject meaningful. We will argue that this difference is based on whether the connection being made is “inward-” or “outward-looking”, thereby differentiating between inward-looking narratives that situated the learner within the story generated around artefact creation, and outward-looking narratives that situated the stories of the content into students’ lifeworlds.

The aesthetic lens described above emerged only as a result of our comparison of the findings of the two studies. Analyses that compare subjects in order to understand and describe teaching and learning have the potential to broaden the scope for laying bare the different elements of pedagogy in each subject. A comparative analysis can also be used to develop more informed and sophisticated descriptions of teachers’ constructions of the classroom, themselves and the subject. By comparing our qualitative studies, we broaden the scope of analysis beyond the subject areas examined by each study and develop deeper insights into the nature and purpose of narrative-based pedagogies that would not have been achieved otherwise.

In this paper we explore the following research question:

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- How do the purposes and nature of narrative-based pedagogies compare across the subjects of mathematics, science and technology?

In the remainder of this paper we outline the case study methodology used for this comparison, as well as the methodology used by both research programs and the participants and analytical processes. Using multiple case study methodology we present the major findings relevant to narrative- or story-based pedagogies in each study. Focusing on the common notion of narrative underpinning teaching and learning in both studies, we then compare the roles that narrative pedagogies played in the three subjects as captured by the two studies. The nature of the connections that can be made through narrative-based pedagogies is then discussed. In this paper we will argue that narrative frameworks have the potential to offer students an aesthetic experience of learning, and that developing a multi-dimensional view of narratives that accommodates narrative frameworks from different subject areas can lead to better understanding of the nature of each discipline and opportunities for adopting meaning-making pedagogies.

### **Methodology: Multiple Case Study**

This paper draws on the findings of two qualitative studies to explore different approaches to incorporating story- or narrative-based pedagogy into science, mathematics and technology classrooms. The two studies and development of findings were carried out independently.

The studies are presented in this paper as separate case studies, one investigating how secondary mathematics and science teachers used story, the other investigating the use of narrative in a

primary technology classroom. By comparing our findings we hoped to gain greater insight into the nature of story- and narrative-based approaches to teaching and learning. The common focus indicated that a case study approach would be appropriate to the needs of the research.

Hitchcock and Hughes (1994, p. 74) claimed that the aim of a case study is to, “locate the ‘story’ of a certain aspect of social behaviour in a particular location and the factors influencing this situation.” This would describe the broad intention of this research into a particular and bounded situation. Mason and Bramble (1997) also consider that case studies “are conducted to foster understanding of how current situations or characteristics developed for practical reasons” (p. 39). This research focused on such “critical problems of practice” (Merriam, 1988, p. xiii), particularly as it related to science, mathematics and technology in the primary school classroom. Furthermore the research was intended to investigate intensively the “factors that contributed to the characteristics of the case,” (Mason & Bramble, 1997, p. 39). In this research this consisted of the classroom experiences of participants undertaking science, mathematics and technology programs. The case study therefore offers a viable means to attain useful research outcomes in that it addresses both the “particular phenomenon and the context in which the phenomenon is occurring” (Yin, 1993, p. 31).

#### *Developing the multiple case study*

Collaboration between the two authors began as informal discussions about our research during our time as teaching colleagues at a regional university in Victoria, Australia. These discussions did not revolve around any intent to form a collaborative research agenda, but merely formed and developed through mutual interests. At some stage in these discussions we noted that two key

concepts underpinned both of our research programs; narrative and aesthetics in the context of teaching and learning, in particular with respect to mathematics, science and technology. We decided to further explore these similarities to see how they might be formulated into a shared understanding of these key concepts.

Table 1 compiles the various elements of our individual research studies that we felt were relevant to the comparison. There were some methodological similarities across the two programs: both were interpretive studies and used categorical and thematic analyses. The difference in research field had to be taken into account because of pedagogical differences that typify secondary versus primary teaching and learning; however the research field was not the focus of the comparison.

<Insert Table 1 here>

The theoretical lenses and contexts were pivotal to our comparison. Both studies explored the role of stories and the aesthetic dimensions of teaching (in author 1's case) and learning (in author 2's case). There were, therefore, some theoretical overlaps that were worth exploring. We had to achieve a common understanding of what we meant by story, both its nature and purpose: this is where the comparison lay as it was through abutting our interpretations that we noticed the different nature of these stories: inward-looking in Author 2's analysis of technology where students told the stories of their artefacts; and outward-looking in Author 1's analysis of mathematics and science where story is used to make the subjects meaningful. This finding was a significant outcome of the process we engaged in that was not evident in our initial individual research. The aesthetic nature of both of these story types became our main interest as we

explored the teachers' purposes, and the learning experiences, associated with the different stories.

The comparison required us to apply our ideas into new contexts: Author 1, into Technology, and Author 2, into science and mathematics. There was therefore a broadening of the context. Below we give further detail on the participants and data generation methods, and methods of analysis.

### *Participants and data generation methods*

The aim of the research by the first author was to investigate differences between the subject cultures of mathematics and science and their impact on pedagogy. Six middle school teachers of mathematics and/or science from two schools (School A and School B) participated in a dialogue with the researcher and each other over a period of about eighteen months. A variety of qualitative methods were selected that would support and feed into this dialogue.

Two sequences of lessons in mathematics and/or science were observed for each teacher in order to gain some insight into the general practice of the teachers. Two of these lessons on two separate occasions (two sequences) were videoed, one mathematics and one science lesson for three teachers, two science lessons for two teachers and two mathematics lessons for one teacher. A total of 20 mathematics and 21 science lessons were observed. The video footage of both lessons on both occasions was returned to each teacher for personal viewing with a set of questions to guide their attention and reflection (a modified video stimulated recall process). A "reflective interview" with each teacher followed the private viewing on both occasions. A focus group discussion involving the four teachers from School A, with discussion based around three

statements arising from a preliminary data analysis, followed the first round of videoing and reflective interviewing. This involved feeding back to each teacher excerpts from their reflective interviews and from literature that related to these statements.

In the research by the second author, the participants were a single combined classroom of grade 6 and grade 4 students in a regional state primary school, as well as their teacher. The students covered the age range of 9 to 12 years. The data were collected utilizing video recording, audio recording, field notes and collection of various artefacts created by the students. Formal and informal interviews were undertaken with both the students and the teacher involved. The data collection was intended to allow the development of a “picture” (Jones, 1997) of student capability in conjunction with teacher perceptions of this capability and the planning and strategies she employed. It was designed to allow insights into technological processes as they appeared from the range of participants’ perspectives (Burns, 1994). Furthermore, the issues associated with the implementation of a technology syllabus were to be explored in-depth. These included classroom strategies used by the teacher involved, the design processes used by the students in the class, the role of assessment in the classroom from the point of view of the teacher and her students, and the manner in which participants characterised technology in the classroom. All names used in this paper are pseudonyms.

### *Methods of Analysis*

In both research programs, an interpretive methodology (Erickson, 1998) was utilized as this approach is able to provide “the meanings and purposes attached by human actors to their activities” (Guba & Lincoln, 1989, p.106). The science and mathematics study used a

constructivist methodology employing hermeneutic dialectic process where inferences and lines of inquiry are cycled and recycled until a consensus (or non-consensus) is reached between the researcher and the participant. Both of the research programs used thematic analysis of responses in interviews as well as observed classroom activity

In the science and mathematics study, lines of inquiry relating to teachers' practices and subject differences and similarities emerged during and following data generation. The first phase of the analysis involved intuitive and continual reflection on classroom observation notes in order to inform interview questions, and for identifying key lines of inquiry from the observations, informal discussions and reflective interviews. Codification of some of the first round of interviews led to the development of three broad interview questions for the focus group interview with teachers at one school. A gross analysis developed categories that related to the three questions, as well as highlighting other key themes that appeared across all of the interviews. All of the themes were explored more deeply in a thematic analysis (van Manen, 1990) that isolated certain elements of the subject cultures useful for drawing comparisons between subjects and teachers. Four themes were selected that highlighted similarities and differences between the subjects in terms of the role that subject culture played in shaping the teaching practices of these teachers. One of those themes, represented in this paper, explored a common imperative to make the subject meaningful by relating the subject to students' lives and interests. This theme interrogated how stories, as a "Story Framework", were used in both subjects, and, by implication, how the rhetoric of "relevance" as a generic pedagogical imperative was translated by the participating teachers into conceptions of the subject, teaching and learning, and into teaching practice (Author 1, 2009a, 2010).

In the technology study, the thematic analysis led to the development of assertions regarding the nature and use of narrative, as a “Narrative Framework”, in the subject area. The analysis of responses to both incidental and pre-determined questions, as well as the discourse and activity from the classrooms, were examined for evidence of common approaches and/or strategies associated with classroom activities. The categorization of responses was undertaken through an ongoing examination of data throughout and following the data collection. For example, possible explanations of student behaviour were identified for testing in subsequent data collection through further questioning of participants and/or focused observations. Assertions developed in this manner were refined or rejected according to their applicability to the context being examined.

The method of analysis used to develop the multiple case study involved looking again at the analysis of each study and identifying classroom events and teacher and/or student perspectives that were similar or different. This analysis led to a differentiation between perspectives that were inward- and outward-looking perspectives on narrative pedagogies. The aesthetic framework provided a useful lens through which to interrogate differences between these perspectives.

### **Findings**

In this section we use experiences and reflections identified by the analysis as narrative-based pedagogies comprising the “Story Framework” in the mathematics and science case study and the “Narrative Framework” from the technology case study. These experiences and reflections are presented here so as to highlight the aesthetic dimensions for the stories or narratives, and the nature of the connections made.

*Case Study 1: A “Story Framework” in mathematics and science*

In the first study, the first author drew on interview data and critical incidents from classroom practice to explore how the six teachers attempted to make the subject matter meaningful by relating it to students’ lives and interests. The analysis targeted meaning-making in terms of being meaningful in the lives of students. The notion of “story” is referred to in both a *typical narrative sense*, where stories about people, objects and experiences are “told” and become part of the teaching and learning experience, and in a *metaphoric sense*, where the lifeworld experiences of the teacher or student and the subject matter are not necessarily woven into a narrative but are linked, demonstrating the cultural and human dimensions of mathematics and science. Storying the subject in these ways reveals something of the “teller’s” understanding of how the subject can link with human experience (Author 1, 2009a). Essentially, the stories serve to situate the subject matter historically, culturally, socially or personally, that is, they essentially humanise the content in order to make it *meaningful*.

The stories emerging from this study mainly focused on making connections between the content and students' lifeworlds. In science, for example, Donna used stories as contexts in order to make the subject matter relevant. Donna selected learning experiences that she thought would be meaningful for students, focusing particularly on making connections between science ideas and students’ interests: “If you’ve got an idea of where your kids’ interests are you can use things like, because in that Year 8 class there’s a lot of girls into horses so you can use different examples where that’s relevant. And the boys: football or cricket”. In some of Donna’s

mathematics examples, students investigated something of interest, for example, investigating fractions using a context that was of interest to them, such as sewing, sales or football:

We did a little thing on statistics, and that was great because the kids could go off and research all their favourite topics. And I found that all of them breezed through that topic, and I thought, yes, that is because that is really connected. [S2AD:138,140]

In science, Donna referred to a task where students explored refraction by investigating “the distance that light comes out of a lighthouse in terms of where the boats are coming, how they work out where to put the lighthouse, does the light run out at a certain point?” [S2AD:126]. Lighthouses were prominent in the lives of these coastal students. Donna emphasised the connective nature of these stories, where theory gains meaning through experience; there is coherence in the experience. In particular, she focused on situations where students were given time and opportunity to investigate their own questions. The aesthetic dimension of these experiences is bound up in the continuity between the experiences at school and from the students' lifeworlds. According to Donna, such contexts promote aesthetic engagement with ideas by emphasising content that is relevant to students themselves and thus possess some motivational value, something that Newton (1988) refers to as relevance underpinned by psychological aims. Donna stated

I think they are pretty important, because I think it actually connects the kids better to actually do their work and it gets them thinking about something. I think [they learn more] if they want to find out the answer

instead of just being told you've got to answer these exercise questions, off you go. Whereas, like I actually want to find this out, I want to know the answer. And if you can do that in terms of connecting into a story, I think it is good, I think it helps them. [S2AD:138] (Author 1, 2010, p. 148)

Pauline's experience of stories in science demonstrates the transformative nature of coming to appreciate the subject. As a science and mathematics teacher in her third year of teaching, Pauline valued stories as a part of her own learning, and endeavoured to incorporate stories in her instruction where possible. In the following quote she explained that, when she was a learner, a science teacher had stirred in her an interest in science through his use of stories. She reflected on the role of stories in her developing interests and subsequently in her teaching:

I like collecting [stories]. I don't think I have enough. I like telling stories and getting the kids' stories out as well. And I have found that when I studied science they were the things that got me excited when a teacher told me a really interesting story and I don't know if mine are interesting or not, but I know that they were the sort of things that got my interest going in science and why I wanted to do more. It is unfortunate but it is true that sometimes it is the teacher's personality, rather than the content that they are teaching that gets kids engaged ... like I had a fantastic Year 10 teacher who revved us girls into doing physics and chemistry in Year 11 and Year 12 and that was more his personality, the way he told stories, his passion for science, that got us into it. [S2AP:48] (Author 1, 2010, p. 142)

The teacher's personality and representation of what it means to appreciate the subject, rather than the content itself, had been instrumental in shaping her perception of science as personally interesting and worthy of attention. The teacher's "passion for science" that was transferred to students through engaging stories that humanised the science endeavour resonated with Pauline on a personal level, leading to identity transformation, and a drive to pursue science. A subsequent interest in science led Pauline to a career in physics and a commitment to science as a way of thinking about the world and informing life's choices.

Pauline's commitment to science was conveyed through the stories she used in the classroom. Stories were a major component of her teaching repertoire. She was able to convey through story her passion, her experiences and her appreciation for what science offers. An example of her use of stories was when she introduced the theory surrounding static electricity with the story of Benjamin Franklin's discovery of electrical charge during lesson P2:

PAULINE: I want to talk about what we did see. Now, Benjamin Franklin conducted a lot of experiments with electricity, his most famous one of course, flying a kite in a thunderstorm with a key attached to the string and having lightning strike that string and then come out of the key. Now he was really lucky that it hadn't rained yet and that the string he was holding wasn't wet because another scientist tried to replicate that experiment only a couple of months later and was killed because of the large amount of electricity going down the string. Benjamin Franklin was really really lucky. So Benjamin Franklin postulated, he came up with this idea, a model... that there was something that he called an electrical fluid that you could put onto

substances and that if you took it away from substances that had one type of charge, and if you added it, it had a positive charge, if you took it away it had a negative charge. We can pretty much say we experienced that charge. The most spectacular thing we did with the van de Graff when we did the discharge rods, what did we see?

STUDENT: Sparks!

PAULINE: Sparks. I always thought that sparks were the most impressive evidence of static electricity... We've got evidence for it. Benjamin Franklin postulated that there were two types, positive and negative. [lesson P2]

Here Pauline tells a story about a scientist's search for understanding natural phenomena. She represents part of the scientific process—Benjamin Franklin postulated, developed a model, experimented, and another scientist replicated. Students' activities in the classroom were linked to the activities of these scientists. She also provides a positive aesthetic response to the phenomenon of static electricity by using such terms as “spectacular” and “impressive”, thereby modelling a fascination with science.

Donna's use of contexts as story situates science within the lifeworld of the student. Pauline's experience of story as a learner enabled her to situate science positively in relation to herself causing a shift in identity as she appreciated the beauty of science as a perspective on the world. Pauline was also able to situate students' activities within the historical context of scientific exploration and knowledge development. In each of these examples, the learner is presented with opportunities to see that science has a place in their lives, and allow human experience to enter the learning process.

Case Study 2: A “Narrative Framework”: Using narrative in technology education

In the study by the second author it is contended that an essential aspect of understanding technological activity in the classroom is to have any artefacts that are developed incorporated into a narrative. The artefact in isolation is difficult to define and may lead to the situation termed an artefact focus (Jones, 1994) that results from emphasising the end product instead of the process. Student participants, such as Helen, noted this when reflecting on artefacts they had made:

Well, with Henry and Kylie they've got a lot of help from Kylie's Dad because Kylie's Dad is an electrician and Henry's Dad's a shire worker or something. So they all had the gear on hand. [IA-04/2] (Author 2, 2005, p.103)

Such statements illustrate the need to have a narrative to accompany any artefacts if one is to make judgments of them. The need for a common framework for technology may be tackled through the use of the concept of narrative. It may be useful to perceive of all technology as part of a narrative, thus providing a reflective tool for the student and teacher, as well as a means to develop assessment protocols based around the narrative of technology activities. The participants in this research found the use of narrative to be a natural means for exploring their understanding of what they had produced, and the responses they provided allowed for some quite detailed insights into their learning. Krystal, for example, when asked about how it was possible to compare two different items that students had made replied that "you can't just really

say theirs is better, because you don't really know how well they've thought of it" [IA-02/9] (Author 2, 2005, p.130). The relationship between the creator and the artefact must, therefore, be established before any object may be meaningfully interpreted. This sort of activity is often the province of historians or archaeologists. What, for example, is the meaning of Stonehenge? To attempt to understand such an artefact requires an understanding of the people who built it, to what purpose they built it and the processes they employed to create it. The mystery is in the relationship of the participants and processes to their creation, not solely in the object itself. This conundrum was recognised by the class teacher, who identified assessment techniques that would be appropriate for the activities her class undertook would be reliant on an active interplay between the creator of the artefact and his/her interpretation of it to others and themselves.

Teacher stories from this technology research indicate that the technological solutions students created had an aesthetic element, although this was usually apparent through Mrs Lange's difficulty in ascertaining how to assess what students had done. When asked how she would assess the artefacts she stated "...how can I compare children who have access to motors and things against someone who wouldn't have any equipment at home?" [EV-01/1] and that "...what was important for me was the children's understanding of what was happening with their particular creation" [IA-06/8]. Mrs Lange was hinting at her need to access the aesthetic understanding of her students, but did not have the experience with the discipline to know how to proceed. As a teacher implementing a new and unfamiliar curriculum she was struggling with underlying notions of what technology actually is, as well as how the children in her class had responded to the design challenges. She stated that assessment had not really been considered "...because we were just trying out the activities involved in it and trying to get a grip on that, rather than how to assess it" [IA-06/11]. For this teacher, there was clear intent to develop an

aesthetic appreciation of the artefact through examining the relationship between the students and their creation, although the reality was that, for her, this did not occur to any great degree.

For students in the technology activities it was apparent that an aesthetic understanding was only possible through the retention of meaningful connections between themselves, the process they had undertaken, and the artefacts they created. Examples of this included students identifying the personal satisfaction derived from their solutions to problems which were expressed through contextualising the issues and the appropriateness of their response. As Kylie noted (Author 2, 2005, p. 132),

....one person might have gone out and bought real flash stuff, like stickers and real good stuff like plastic and have it carved professionally and paid a heap of money to get this real flash little car. And someone else made something that did exactly the same but it wasn't as flash looking and you'd give the person more marks for using limited resources. [IA-02/11]

This appreciation for the process is driven by a value judgment of the intellectual endeavour applied to solving problems utilising an inward-looking, or reflective, narrative that maintained, even highlighted, the necessary connections between process, artefact and participant. It was evident from the research that the students had a more clearly articulated view on the aesthetic appreciation of their artefact than their teacher. It would appear that this was due to the teacher being an 'outsider' to the creation process, as well as a lack of clear assessment protocols. The teacher knew that multifaceted learning had occurred and that it required an

understanding and appreciation of each student's narrative, but did not know how to engage herself into the student's experiences.

## Discussion

Evident in the case descriptions are two themes relating to the purposes and nature of the narratives explored in each study: how, what and why connections were made for students through the different types of narratives, and the aesthetic nature of these narratives. Narrative or storied approaches in education have a rich history (see for example Clandinin & Connelly, 1990), however aesthetics is less well attended to. The discussion explores both of these themes separately, firstly providing a multi-dimensional view of narrative, followed by a discussion of the importance of recognising the aesthetic nature of these types of learning experiences

### *A multi-dimensional view of narrative*

It is a characteristic of humanity to seek connection: “This sense of connectedness is not only at the level of individual cognition; it comes from a desire to know with one’s heart and mind, emotions and cognitions, imagination and reason” (Girod & Wong, 2002, p. 199). Narrative provides a way of focusing on connections between the subject and the learner. Research by Boström (2006), for example, examines how students and teachers used stories of their lived experiences to make sense of science ideas. She found that narrative discourse in the classroom opens up possibilities for connecting theoretical chemistry with real life. However, what is the nature of this connection? The comparative lens used in this study enabled recognition of the

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different ways stories or narratives play make connections in the classroom. On closer analysis, the nature of connections made in the two studies were subtly different.

The science and mathematics study focused on the tendency for mathematics and science teachers to make the subject relevant and meaningful by using different types of ‘story’ that situated the science or mathematics content within the lifeworlds of their students. *The focus is on connection of science and mathematics with the human experience through story.*

The technology study looks at how classroom technology activities require the development of a narrative that defines the meaning of any created artefacts. This interplay is called a narrative because of the necessity to involve the experiences and expectations of the participants to establish the meaning of any artefact to them. The interpretation of artefacts, from the point of view of the teacher and the students, was contextualised in terms of relationships between the artefact, its creator(s) and its user(s). *The focus is on the story of the human experience through technology.*

Common to both studies was an interest in exploring the role of narrative, or story, in teaching and learning. A pedagogical imperative of teachers in both studies was to ensure that there were opportunities for students to connect with the subject. In looking deeper for commonalities we will use the term “narrative framework” to refer to this common thread. On closer examination, we recognised that the nature of connections made through narrative frameworks differed across the case studies.

In science and mathematics, the narrative framework has the potential to create relevance for participants through the construction of meaning in a broader context. Pedagogic practice focuses on making connections for students by drawing on narratives that resonate with their lives and aspirations. As such, the narratives are *outward-looking* and allow students to extend

their learning beyond the immediate context of the classroom. This contrasts with the role of narrative in the technology classroom. Narrative in this context is *inward-looking*, creating meaning for artefacts and activity within the classroom by focusing on the story of its creation. Pedagogic practice in this regard is about maintaining connections that are attached to objects, artefacts and practice.

Highlighted by these two narrative perspectives is that different connections are made through the construction of narratives.

Outward-looking narratives focus on student connections with the subject matter in order to situate the subject matter meaningfully in students' lives. Some of the stories are designed to raise students' awareness of science or mathematics in society or drew from students' interests, thus drawing their attention to connections that are not immediately apparent. Assumed in such narrative experiences is that, in science, natural phenomena are separate from the individual and that students therefore encounter or experience them; while in mathematics, humans are seen as interpreting and seeing patterns in natural phenomena or in number patterns. The individual is situated outside of the phenomenon, while at the same time situating the phenomenon into the lived experiences of the individual. Narratives were drawn from outside of the individual in order to make an external phenomenon or process meaningful. The pedagogical imperative is therefore to focus on the connection of the subject matter with personal experience.

As a discourse operating in both mathematics and science, relevance and relating the curriculum to students' life worlds is well established as being important in making the curriculum accessible and meaningful for students (Education & Training Committee, 2006). For instance, the curriculum documents of the Victorian Essential Learning Standards (VELS) for mathematics and science recognize relevance as one of the premises of the Discipline-based

learning strand: “students develop deeper understanding of discipline-based concepts when they are encouraged to reflect on their learning, take personal responsibility for it and relate it to their own world” (VCAA, 2005, p. 3). The proposed Australian Curriculum states that during Years 3-8 “Students increasingly look for and value learning they perceive as relevant, consistent with personal goals, and/or leading to important outcomes” (ACARA, 2010, p. 12). However, such a focus will depend on teachers understanding how relevance can enter mathematics and science classrooms in a meaningful and appropriate way.

An example in technology of an outward looking perspective can be seen in the design brief where the imperative for a new design solution is presented to students. In the study discussed in this paper students were asked to design a vehicle that (among other criteria) was environmentally friendly. As such, they were asked to reflect on the broader context of the design problem and to present a solution that demonstrated they had taken this into account. In the design brief students are therefore being asked to resolve a “complex inter-play of intentions” (Elmer, 2002, p. 24) that include outside considerations (Environment/broader societal issues) as well as personal intentions that are more inward looking.

Inward-looking narratives emphasise the personal transaction of learning itself. The experience of learning adds to the gamut of experiences that a person builds up over a life term. The connections are immediately apparent to students because they have been constructed by the student through the creative endeavour. According to Dewey (1963), current experiences form the foundation for future experiences. Learners’ backgrounds and experience with the subject provide the sum of their “lived experiences” (van Manen, 1990) from which they can draw when attempting to situate the subject matter into a meaningful framework. This perspective is perhaps demonstrated in technology where the narratives built around technological tasks emphasise the

creative process and situate the learner as the orchestrator and creator of the phenomenon. Pedagogy focuses on connection of the subject matter to students by engaging them in the process. In this regard the student is an active participant in the creation of the narrative aspects of technology. The “complex inter-play of intentions” (Elmer, 2002, p.24) in this case are focussed on the personal and, we would argue, require students to exhibit meta-cognitive strategies that enable them to develop a solution that uses knowledge “in support of thought leading to creative expression” (Lewis, 2005, p.46), and should therefore be judged in a manner that recognises the “effort and imagination that has been applied to the modelling process” (Davies and Elmer, 2001, P.167). This requires evidence of connection between the created artefact, the creators and users and is seen in the development of a narrative that, in technology, emphasises the personal creativity of the solution and is, therefore, what we have termed here an inward-looking narrative.

While this inward-looking narrative perspective was not included in the stories emerging from the science and mathematics case study, this narrative perspective offers students and teachers opportunities to build narratives around participation in the processes of the disciplines. Where instruction allows them to appreciate and participate in the human endeavour of mathematics and science, students can experience how ideas are generated out of human exploration, intrigue and need. Students may participate in this human endeavour by engaging in modelling, investigations, or open-ended inquiry where they are the orchestrators of that inquiry, or design, creativity and technological processes when they apply their science or mathematics understanding in the production of artefacts. When students are encouraged to build narratives around such inquiries or artefacts, the narratives become inward-looking. For example, in such instances, the narrative becomes an unfolding creation, where students’ views of the subject, and

themselves in relation to the subject, are transformed through participation. Through such narratives teachers can gain a greater appreciation of the connections that were involved in the production of the inquiry or artefact, and are therefore embedded and part of it: the experiences, knowledge and people that informed the process; how and what decisions were made and why; and the intended purposes, hopes and challenges they faced. A complex web of connections becomes quite apparent when such narratives are added to students' learning experiences.

The nature of these two perspectives on narrative are summarise in Table 2.

<Insert Table 2 here>

*Amplifying the aesthetic nature of narrative learning experiences*

Illustrated above is the potential for narrative-based pedagogies to evoke a personal response in the learner. This response is aesthetic in nature, meaning that a value judgement is placed on the experience by the learner. Such relationships were illustrated in the case studies. For example, for the science teacher, Pauline (case study 1), hearing stories from an inspiring teacher was transformative and led to her life-long appreciation for science. For the technology student, Kylie (case study 2), her narrative enabled her to express how her ingenuity and innovation in the face of limited resources was something to be proud of.

Table 3 describes how the dimensions of aesthetic understanding may be attended to within the classroom, depending on the narrative perspective employed.

<Insert Table 3 here>

A point of differentiation in the two perspectives is in how learning brings unification and coherence, with connections between subject matter and students' lives being the focus in the outward-looking perspective, and connections being made through the process as the focus in the inward-looking perspective. The compelling and dramatic nature of understanding differs in where the beauty or elegance lay – in learning about the content versus participating in the process. How the story sits in relation to the student also differs, with inward-looking perspectives situating the stories of the subject within the lifeworlds of the students so as to make the subject matter meaningful, compared with situating the learner within the story of the creative process so as to recognise the human ingenuity and endeavour associated with the created artefact.

This framework can be applied to any subject area. It helps to identify the different aesthetic associated with content- and process-based approaches to narrative – one that shows how the content is relevant to students' lives, another how participation in the processes can lead to appreciation for one's efforts.

### **Conclusion**

By examining three subjects, as represented through the findings of two different studies, we have attempted to examine the complexity of the notions of story and narrative as they can be applied to the classroom.

We advocate a multi-dimensional view of narrative pedagogy that acknowledges the multiple forms of narrative, multiple sources that can be drawn upon in narrative construction, and the multiple connections that can result. In our comparison of how narrative frameworks are used in science, mathematics and technology, we have, therefore, found it most useful to think of

many different narratives, and many different purposes for their use. Incorporating a multi-dimensional view of narrative into teaching enriches teachers' response to a generic school (or pedagogical) imperative to connect the subject to students' lives by creating a web of connections that makes coming to understand an aesthetic experience, where the personal response connects the emotional with the cognitive. Through such experiences learning becomes resilient, rigorous and flexible.

We also argue that narrative frameworks have the potential to add to students' aesthetic experience of learning, and have the potential to lead to an aesthetic understanding of science, mathematics and technology. This aesthetic understanding arises out of a deep, complex, and ultimately transformative experience of the subject. By comparing the nature of the aesthetic understanding gained through inward- and outward-looking narrative perspectives, we have shown that a multi-dimensional view of narratives has relevance in a variety of discipline areas.

While research into the use of narratives as pedagogical tools is not new, our comparison of the aesthetic nature of such learning experiences in different subject areas opens up lines of inquiry into subject differences. Such explication has value for teachers who are unclear of how narrative might be woven into teaching, particularly in terms of how the student makes connections with the subject. The nature of narratives used in teaching and learning depends on the aims of the subject, the nature of the content, and the process of inquiry that is promoted in that subject.

Further research into other curriculum areas is clearly warranted, and the nature of narrative as a means to engage students and enhance teaching practice is also an area of research that warrants further work. Research that compares the narrative frameworks used in other subjects, even across cultures, can give important insights into the assumptions underpinning the

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nature of the knowledge and inquiry, and what is valued and promoted in the teaching of these subjects. Further, we would argue that the aesthetic experiences of students should be foregrounded in any research into effective pedagogy.

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Table 1.

*Elements of Each Research Study*

	Case Study 1	Case Study 2
<b>Focus</b>	Teachers' experience of subject cultures of science and mathematics, and how they shape pedagogy	A single researcher and her class coming to terms with a new curriculum area, design technology
<b>Relevant Findings</b>	Use story to make meaning in science and mathematics Aesthetic understanding of teachers	The teacher and her class used narrative to understand the artefacts they created
<b>Theory</b>	Aesthetic experience Narratives enriching the learning experience	Narratives enriching the learning experience
<b>Contexts (Subject)</b>	Mathematics and science	Technology
<b>Research Field</b>	Secondary school Multiple classrooms with a focus on the teaching Multiple schools	Primary school Single classroom with a focus on learning and teaching Single school

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<b>Methodology</b>	Interpretive study Observations and videos of classrooms, individual reflective interviews with teachers, focus group interviews with	Interpretive study Observations and videos of classrooms, reflective interviews with teachers and students, and the collection of artefacts.
<b>Analysis</b>	Categorical and thematic analysis	Categorical and thematic analysis

Table 2.

*Inward- and Outward-looking Narrative Perspectives*

<b>Narrative Perspective</b>	<b>Outward-looking</b>	<b>Inward-looking</b>
<b>Nature of connection</b>	<ul style="list-style-type: none"> <li>Reconnecting, making connections between phenomena and processes that may not be readily apparent to learners</li> </ul>	<ul style="list-style-type: none"> <li>Maintaining connections between artefacts and processes that are already apparent to learners</li> </ul>
<b>Situates the learner:</b>	<ul style="list-style-type: none"> <li>Outside of and independent of the phenomenon</li> </ul>	<ul style="list-style-type: none"> <li>As orchestrator and creator of the artefact</li> </ul>
<b>Narratives:</b>	<ul style="list-style-type: none"> <li>Are drawn from outside of the individual to make an external phenomenon or process meaningful</li> </ul>	<ul style="list-style-type: none"> <li>Are of an unfolding creation that must include the learner</li> </ul>
<b>Pedagogy focuses on:</b>	<ul style="list-style-type: none"> <li>Connecting subject matter with personal experiences of the student</li> </ul>	<ul style="list-style-type: none"> <li>Connecting subject matter with students through participating in the creative process</li> </ul>

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Table 3.

### *Dimensions of Aesthetic Understanding and Different Narrative Perspectives*

<b>Dimensions of Aesthetic Understanding</b>	<b>What it means for the learner</b>	<b>Narrative pedagogies allow for this by:</b>	<b>Outward-looking perspective</b>	<b>Inward-looking perspective</b>
Compelling and dramatic nature of understanding	A learner's interests and passions provide motivation in learning	Drawing on students' interest, and acknowledging what motivates them in life and within the learning experience	Appreciating the beauty of disciplinary ideas and modes of inquiry	Capturing the elegance and personal satisfaction involved in solving problems
Learning that brings unification or coherence to aspects of the world	Knowledge that is intrinsically and extrinsically connected	Making connections between events and ideas within the learning experience; and between school-based learning and students' lifeworld experiences	Connecting subject matter with personal experience, relating content to students' interests, generating interest and emphasizing utilitarian purposes of the subject	Making explicit tacit connections made through the creative process; broader implications not just focused on

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				technical skills
Perceived transformation of the person and the world	Identity develops through experience	Storying who they are, and the type of person, learner, and consumer that they are and want to be	Allow for identity construction that recognises that disciplinary knowledge has a place in their lives, allows human experience to enter the learning process, situating the story within the lifeworld of the student	Allow for identity construction that is bound up in the creation of the artefact, situating the learner within the story