Challenging current approaches to early technology education

Robin L. Hall[1] and Lynette Schaverien[2]

University of Technology, Sydney, Australia

Abstract

Most previous early technology learning research has reported children's responses to short, intensive teacher-directed topics in diverse settings. Few studies have tracked children's sustained investigations of their own technological questions.

Rather than examining a young child's appropriation of his teacher's technological narrative, this study described and analysed a child's own narrative, in the telling, in a wide range of contexts, over an extended period. To do so, one of us participated in one young child's inquiry of his own technological question at home and in his extended community over a two-year period, describing how he exploited those means available to satisfy his curiosity. Plato's *Meno* questions (about the subjects a learner selects, his methods of inquiry and whether he knows he has learnt) provided a framework with which we could then gauge the development of this young child's ideas about technological phenomena. Findings reveal the educational significance of this child's pursuits: they qualify as learning, highlighting his capabilities and the sustenance they receive within his community.

This study provides a model for technology teachers of young children, demonstrating how they might adopt an active role alongside other members of children's learning communities so as to nurture young children's technological capability, and an analytical framework by which such capability can be judged. Implications can be drawn from this research for the feasibility and worth a new kind of education in an information age, one in which children have greater control of curriculum. Moreover, the three *Meno* questions provide a new and significant basis on which children's technological capability can be assessed. Such re-thinking challenges present teacher education in technology.

1 Introduction

With rapid cultural change comes increased interest in the technological contributions of young people. Rudge (in Henry and Hampton, 1994) predicted that "young" engineers will be the creative designers of key technologies in the next age of information. Lowe (2000) asserted that educating for the twenty-first century meant, "equipping *all* to shape the future – not just *cope* with changes" (emphases in original). So, cultures expect education to create young people "who are capable of doing new things, not simply repeating what other generations have done" (Piaget cited in Duckworth, 1964, p. 175). Technological capability[3] is therefore highly prized in a rapidly changing technological world.

The younger generation appears to have a sense of its purpose as well. Increasingly, in classroom-based studies young children demonstrate their ability to go beyond simple exercises planned by teachers and researchers. For example, they initiate their own design

[1] University of Technology, Sydney, Eton Road, Lindfield NSW 2070.
[2] University of Technology, Sydney, Eton Road, Lindfield NSW 2070.
[3] The term 'technological capability' as used in this paper recognises that technological ability comprises the capacity to be creative on the one hand and discerning on the other about societies' technological directions (Piaget cited in Duckworth, 1964; Postman, 1993).

briefs (Fleer, 2000a); they make models which strongly correlate to their own designs (Fleer, 2000b); they draw on their everyday experiences to construct devices of their own choosing (Anning, 1994); they "see themselves in the pilot's seat (or the director's chair)" in digital media environments (Goldman Segall, 1997, p. 2); and they find solutions to technological problems from their life experiences and imagination (Twyford and Jarvinen, 2000). Researches gained such insights by informal interviewing (e.g., Anning, 1994; Fleer, 2000a, 2000b; Goldman Segall, 1997) and structured interviewing (Twyford and Jarvinen, 2000) and by audio and video taping (e.g., Anning, 1994; Fleer, 2000b; Goldman Segall, 1997) and at times set by researchers (such as a particular one and a half hour-period per week over a ten-week period (as did Fleer, 2000a), during a two-week technology teaching sequence (Fleer, 2000b) and over two particular weeks in concurrent years (as did Anning, 1994)).

Such research documented children's responses to short, intensive teacher-directed topics. However, few studies appear to have described or analysed children's personal discoveries about technological phenomena, nor how such ideas might develop *over time*. The present study attempted to do so through a detailed single case study of how one child develops his own technological ideas, within his community, over a two-year period. So, rather than examining a young child's appropriation of his teacher's technological narrative, our study described and analysed a child's own narrative, in the telling. We asked whether this child was able to learn by pursuing his own technological question, at home but without explicit teaching, over a sustained period of time. In doing so we confronted the challenges of evaluating the educational worth of one child's idiosyncratic inquiry. Viewed alongside a growing number of reports critical of technology education as being "historically bound and ill-suited for today's world" (Hurd, 1991, p. 723), such findings have the potential for bringing about change in the ways teachers approach young children's learning in technology.

2 Research Design and Methodology

We reported elsewhere the particular circumstances that opened the way for Robin to investigate and participate in a young child's (Dean's) initiation and pursuit of his own technological question (Hall, 2001). As Dean drew Robin into his inquiry, she tried to be available to him at times when he wanted to pursue ideas with her, at times such as mornings, afternoons, evenings, weekends, school holidays and family celebrations (e.g., Christmas and birthdays) and in various locations such as homes (his and Robin's) and settings within homes (e.g., living rooms, computer rooms, garages, gardens, courtyards, at front doors and on front porches), places of interest in the community (e.g., diagnostic laboratories, solar workshops, solar centres, electronic stores, retail stores, shopping malls, car parks, offices including his father's, Robin's and colleagues', auto repair centres and camping sites) and in cars (his family's and Robin's).

Similarly, Dean responded positively to Robin's participation in his inquiry, for example, by receiving her telephone calls at various times of the day and evening, by replying to her email messages, by recounting conversations with family members (e.g., parents, siblings, grandparents and uncles), with members of the community (e.g., auto repairpersons) and with peers (e.g., school friends who had also participated in our pilot study), by participating in conversations when he accompanied her to places of interest (e.g., with salespersons, watchmakers, technicians, solar energy technologists, computer technologists, doctors, radiologists, Robin's husband and colleagues), by providing her with documents he had produced (e.g., accounts of events, lists of his own observations, stories about how things work, instructions setting out how to use devices, letters to family members and their replies, his innovative designs and stories about how they might work) and various artefacts (e.g., reference books, log books prepared for community-based science competitions, photographs,

X-rays, birthday gifts and novel devices) including artefacts he designed, made and operated (e.g., solar cells, solar ovens, circuits, electrical fans and handheld tools).

Much of our data gathering took the form of everyday conversation, obeying the principles of such conversations, principles that were fundamental to the conversational research methodology developed by Cosgrove and Schaverien (1996). This approach to data collection relied for its success on the development of relationships based on mutual respect and trust. It enabled us, to use Peshkin's (1988) words, "to be there" (p. 417). As an interested and collaborating adult, Robin was sometimes an explicit conduit for the child's inquiry itself, just as other members of the child's community were. So, our study had features of Heath's (1993) earlier studies of the communities of Roadville and Trackton in which she immersed herself in the lives of people, "living, working and playing with children and their families and friends" (p. 259), even ten years on.

Over a two-year period we documented every event to which we were privy of a young child's pursuit of his own technological question. Our primary data consisted of a large collection of interconnected stories, serendipitously gleaned. A way of gauging the educational value of what this child did was needed. The *Meno's* three questions (Newell and Simon, 1997) appeared to us to provide an appropriate framework by which to do so:

> (1) How does [this young child] inquire into something he does not already know? (2) What subjects does he set forth? (3) If he finds out, how does he know that this is what he did not know? (p. 97)

We now describe the use of this framework to gauge the educational significance of this child's technological inquiry.

3 Gauging the Educational Significance of This Child's Own Technological Inquiry: An Analytical Framework

In this section, we deal, in turn, with each of the *Meno's* questions.

3.1 The *Meno's* Question (2): Dean's Subjects of Inquiry

Over the two-year period of our study, it seemed to us, that Dean chose his subjects from three broad areas of interest:

Group 1. The working of technological systems and their components (devices, components of devices and at times, components of components of devices). This group included telephone, computer, audio recording, battery, time keeping, imaging, solar, video recording, wind technologies and a diverse range of other electrical technologies. For example, his interest in solar technologies included thought experiments such as his cassette recorder, his soccer trainer and his computer, devices he made such as his electric fan, his solar oven, his solar boat and his solar cells, generating devices such as panels, cells, grids and battery chargers, domestic devices such as solar-, battery- and dynamo-charged radio/torches, ovens and radios, waterside devices such as navigational beacons and buoys and other devices in the community such as electronic calculators, street lights, camping facilities, trailers, farm fences and cars.) Inherent in his inquiring was an emerging philosophical wondering about the nature of things (e.g., the nature of communication, computer language, stored information, magnetism, electricity, batteries, time, solar energy and images).

Group 2. Connections between technologies. Here, Dean seemed to have to put together devices, either by envisaging connections as they might be or by using various devices available at the time. He imagined future technological connections (for example, his thought experiment of

"television that [could] connect to the telephone ... so [callers could] see each other"). He chose to operate various devices simultaneously (e.g., telephone and crystal radio, calculator, radio(/torch) and computer) and he made actual connections (for example, he operated the connection he had made by linking four telephones: his fixed telephone, his cordless telephone, his mother's fixed telephone and Robin's fixed telephone).

Group 3. Handheld tools. This group included the functions, working and making of tools, what Golinski (1998) described as "the material tools the human investigator uses to disclose, probe, isolate, measure, represent, or otherwise bring to attention the objects of investigation" (p. 133). Dean's interest was evident in his use of instruments for dismantling (e.g., slot-head, cross-head, watchmaker and electric screwdrivers, spanners, scissors, knives), for testing (e.g., magnifying glasses, compasses, bradawl, hand lenses, jumper leads) and for measuring (e.g., voltmeters, manual battery testers), and his making of instruments for utilising (e.g., his storing tool, his retrieving tool and his rotating spit with handle) and for communicating (e.g., his door buzzer).

Thus, Dean's subjects included both envisaged and actual systems: he pondered how technologies might develop in the future and as well, he was interested in devices already at work in the culture. As a consequence, both electrical and renewable energy systems, those driven by solar and, to a lesser extent, wind, became subjects of his inquiry. However, whilst this list shows the *spread* of his subjects, he also appeared to develop them in a variety of ways as evidenced by this list:

> by his steady and persistent selection (e.g., his study of telephone, computer and battery technologies, connections between technologies and handheld tools extended over the entire two-year period),
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> by his short, focused burst of interest (e.g., his choosing to consider the working of diagnostic devices such as ultrasounds, CT scanners and X-ray machines, DVDs and wind-powered technologies), although further time might have shown his inquiry into them nevertheless continued,
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> by his closure of subjects and at times, his later resumption of them (for example, after a period of three months he drew his investigation of tape recorders to a close and later he refocused on tape recorders with auto-reverse functions, after a break of four months,
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> by his recognition of the potential for inquiry of serendipitous events (for example, a slip of a screwdriver alerted his interest in magnetic audiotape and later, in video tapes, computer tapes, floppy disks and CD-ROMs, and a spark from a battery, in power supply boxes in VCRs and in the nature of electricity and magnetism) and a birthday gift of a novel device (a solar-, battery- and dynamo-charged radio/torch), in radios, dynamos and the nature of solar energy.
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> by his choosing of subjects on his idiosyncratic time scale (for example, whilst inquiring about mini disk technologies at *Sony*, a promotional brochure on a counter served to quicken his interest in digital cameras) and mostly,
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> by simply being in unexceptional places, doing the ordinary things of life (for example, accompanying his father to his office fired his interest in computer hard drives, sitting at the family dinner table, in the evolution of computer technologies, hearing a clock strike, in pendulum clocks and the nature of time, noticing reflections from a stained glass window, in colour and the nature of images and catching a

glimpse of something in his cousin's garage amidst, what he described as, "all the junk", in answering machines and the nature of stored information).

However, there were many instances when Dean went about things and we were not even aware of the subjects he might by pursuing (e.g., when he chose to listen to his voice on Robin's voicemail, to look into her reverse-cycle air conditioning unit and to closely study her video camera).

Some insights into how Dean actually went about *choosing* his subjects were available to us, for example, in his selection of subjects in Group 3 (handheld tools). Here, his subject choice was largely dependent on the task at hand (for example, when he wanted to cut audio tape, he used scissors and to remove the outer casing of batteries, saws). Various types of tools also attracted his attention (for example, when he needed to remove screws from tape recorders, he investigated the use of slot-head screwdrivers, from electronic games, watchmakers' screwdrivers and from VCRs, cross-head screwdrivers). When he needed to perform a task for which there was no suitable tool on hand, his interest focused on how handheld tools are made (for example, when he needed to store screws, he made his own tool using the magnet of a loudspeaker from a tape recorder). In fact, Dean's study of handheld tools was shown to be critical to his selection of subjects: the availability of relevant instruments often determined his choice of subjects (for example, without an electric screwdriver, his study of power supply boxes was curtailed and having a bradawl on hand meant that he was able to continue his study of batteries).

As already indicated, Rudge (in Henry and Hampton, 1994) asserted that the application of the key technologies – electronics, photonics, software engineering and wireless – would be the foundation of telecommunications, computing and the information technology industries in the twenty-first century. Others, too, have highlighted these four key technologies

> as major enabling factors in this global transformation (e.g., of electronics, Berry, 1993; of photonics, Hoagland, 1994; of computer software, Roll in Tiffin and Rajasingham, 1995; and of wireless, Radding, 2000) and
>
> as embedding seminal technological concepts such as modularisation, systems and information engineering, feedback, miniaturisation and the language of electronics (e.g., Forret, 1997), laser and imaging (e.g., Berry, 1993) and solar energy (e.g., Centre for Photovoltaic Engineering, University of New South Wales, 2000), digitalisation, protocol and transparency (e.g., Hillis, 1998; Kohanski, 1998) and design, security and bandwidth (Wallace, 1999).

In fact, we found that Dean's subjects of inquiry fell into these same four groups:

> Electronics (e.g., his interest in telephone, audio recording, computer, battery and time keeping technologies and as well, in the nature of magnetism, electricity and batteries),
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> Photonics (e.g., his thought experiments such as his solar-powered animal detector, cassette recorder and computer and as well, in the nature of solar energy and images),
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> Software engineering (e.g., computer technologies such as software programs, auxiliary storage hardware and the internet and as well, in the nature of computer language and stored information) and
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> Wireless (e.g., connections between technologies, telephone technologies, garage door remote controls, crystal radios, sensor-controlled Christmas tree message and as well, in the nature of communication and ethical and privacy issues).

Significantly, Dean was able to select many subjects in which seminal scientific and technological ideas are embedded. For example,

> His study of electronic devices focused on how information might be transferred by telephones, modems, tape recorders and radio/torches and how information is displayed on audiotape, on printer copies and on computer, voltmeter, calculator and television screens. Within such subjects lies the potential to uncover ideas of storage, transfer and retrieval of information in analogue and digital forms.
>
> His interest in photonics incorporating concepts such as laser, solar and imaging resonates with the surge of research over the past three decades in technologies designed to harness light energy.
>
> He selected a range of software engineering subjects that embed concepts of digitalisation, protocol and transparency. For example, his sense of digitalisation was most clear in his explanation of the working of scanners: "Well – it's sort of like a printer – just like the printer *remembers* what to *write* – well, the scanner *remembers* what it *scans* – you can buy these special scanner cartridges – that you can put into your coloured printer, I think".
>
> His interest in wireless technologies focused on the concepts of design (e.g., his connections between televisions and telephones), security (e.g., the use for passwords) and bandwidth (e.g., his toying with the idea of what he called "the space" occupied by megabytes). Furthermore, in his choosing to use devices simultaneously lies the potential to unravel the idea of convergence.

Thus, in the *spread* of ideas underlying all four key technologies (electronics, photonics, software engineering and wireless), there was evidence of an alignment between Dean's self-chosen subjects of inquiry and those currently driving Western technological advance.

Such alignment was also evident *chronologically* within the development of his inquiry over time. As Dean handled devices and talked about them with others, he was often curious as to its roots: how it came to be the way it was. Frequently, he envisaged how it might be in the future. At times, he demonstrated his interest simply by choosing to inquire about the things that have interested others in the past. Consequently, Dean was concerned with the development of a diverse range of systems: communicating, computing, counting, audio recording and video recording. For example, his interest in the development of computer technologies featured prominently in his inquiry: early computing machines (e.g., computers "as big as a *room*" as his father had used), current electronic computers (e.g., palmtops with modems "as small as credit cards" and "minute" hard drives he himself used) and new possibilities for computer systems (for example, he proposed three ways forward: networking of devices with its resultant networking of information, machines powered by renewable energy sources and intelligent machines). Scarcely 50 years after its invention, the computer is already listed with the wheel, the printing press and the steam engine as a technology that has changed the world (Kohanski, 1998).

So, the second *Meno* question allowed us to identify the degree to which this young learner was able to glean subjects of inquiry from his culture and the high cultural value of his choice. Through his complex network of subjects, Dean seemed able to sense the culture's technological evolution. Implicit in his choice of subjects appeared to us to be an overarching desire to understand information handling echoing movements in the culture towards these same problems.

4.1 The *Meno's* Question (1): Dean's Methods of Inquiry

Next we considered this child's modes of inquiry. To do so, we drew on Schaverien and Cosgrove's (2000) model which recognised six acts – exploring, designing, making, operating,[4] explaining and understanding – as occurring contiguously in natural learning situations.

Exploring seemed to be Dean's most favoured method of inquiry. Personal value often appeared to drive his exploration (for example, even before our first meeting, he chose to dismantle his own tape recorder and he expressed satisfaction when he was able to examine a second device), at other times, familial value (for example, his exploration of imaging technologies appeared to quicken with his mother's professional interest in diagnostic devices) and sometimes, cultural value appeared to be the driving force (for example, his need to explore the contents of batteries appeared to be provoked by his awareness of community-based recycling programs). "On [such] a background of value" (Edelman, 1992, p. 118), he often became absorbed in his exploratory activities as he did, for example, when he explored an electronic game, dismantling and reassembling its components for more than one and a half hours, and mostly in silence, until he was satisfied that he had achieved what he wanted. At other times, his exploring evoked expressions of delight (for example, after exploring text-to-speech synthesis, he laughed loudly as he imitated its robotic sounds, and Robin did, too). His exploring appeared to nurture the rich variation that is a part of natural, early, language learning (Pinker and Bloom, 1990). For example, he explored ideas through the use of rhetorical questions, for example, wondering aloud whether there were microchips in a discarded computer and finally commenting to himself, "Yeh! There they are". His use of tools serves to illustrate the often stringent tests he undertook in his exploration. For example, when he wanted to see what was under the electronics board of a tape recorder, he needed to test one and then another of the tools he had available – screwdrivers of various sizes and styles, spanners and scissors – before he chose to focus on the suitability of a slender screwdriver to prise it from the case. Only then was he in a position to explore the integrated circuit of a tape recorder. So, his exploring served to generate further ideas about his subjects.

Designing enabled Dean to test his ideas about subjects. He often generated and tested his ideas through what Ferguson (1992) described as the "visual language" (p. 41) of his design drawings, graphically displaying what he saw in his mind's eye (for example, he designed his pain scale incorporating accessories and components – graduated scale, electric power plug, connecting cord and sensors – which would enable his device to work in the way he envisaged. At other times, Dean's designs were in the form of verbal descriptions (for example, he explained the design of his car security system, "You could get an alarm that you just touched the car and the alarm would go on ... but that would be a problem. If you leaned on the car, the alarm would go off!") At other times, this testing went on in the deep recesses of his mind, in his making and operating of devices, in his visualising of future technological developments, in his altering design drawings and in editing his web site, again and again. Whatever its form, his designing was a dynamic process.

Making and then operating were the culmination of Dean's design efforts. For example, he made circuits by connecting motors from dismantled tape recorders, by using batteries of different voltages and by substituting solar cells for batteries.[5] He made fans using 1.5-volt and 6-volt batteries. At times, his constructions were particularly innovative (e.g., his buzzers made by connecting the wires of a loudspeaker to the terminals of 9-volt and 6-volt batteries, his boat, driven by a water-damaged solar panel, his solar oven, incorporating a rotating spit

[4] Cosgrove has suggested and Schaverien and Cosgrove have discussed, but not yet written about, this sixth act of learning, 'operating'.

[5] Dean did not labour over precise distinctions between battery and cell. He used – and indeed, we, too, used – these words interchangeably.

and his solar cells, using strands of twisted wire. At times, materials were not available for his making and he needed to improvise. For example, when he wanted to make his solar oven, he covered his cardboard panel with aluminium foil and fashioned his rotating spit using the wire of a coat hanger. So improvisation became invention. At other times, he operated ready-made devices, designed and made by others. Again, without his actual using such devices as telephones, personal computers, laptops, palmtops, printers, scanners, tape recorders, mini disk players, garage door remote controls, coffee makers, minute timers, still cameras, ultrasound heads, X-ray light boards, calculators, radio/torches, televisions and VCRs, he could not be sure if they worked.

Explaining his ideas about the world often appeared to generate further answers for Dean: his explaining was not an endpoint but rather, it allowed him to push his ideas further. He frequently chose to explain concepts through spoken language. For example, in his use of expressions such as "as quick as lightning", "it's just very *quick*" and "it all goes so *quickly*!" he seemed to recognise that there were some things – like electricity – which appeared to exist within microscopic scales of time. It was often through the answering of his own questions that his ideas developed. For example, he wondered about the working of garage door remote controls and then recognised such devices worked "like TV remote controllers". At other times, his questions were more in the form of mulling over ideas than seeking or giving information. For example, he frequently used the expression "I wonder" as he considered subjects such as whether mini disks were like CDs, "how solar power comes from *heat*" and "how it gets up (comes) from the sky". He frequently used language to explain particular ideas or views he held. For example, of the effects of electrocution on the human body, he explained, "[The electricity] sort of – you can't let your hand go – it sort of *forces* your hands onto [the object] ... your fingers are magnets". At other times, he used the written word to explain ideas. For example, he wrote lists of instructions about how to use printers, directions, about the working of his electric pain scale, warnings about the dangers of electrocution, facsimile messages about the environmental benefits of solar energy and e-mails about how his soccer trainer might work. As others have done in the past (e.g., Sacks, 2001), he also chose to manipulate language to explain concepts (e.g., his use of the words "signallers" and "feelers" to explain the work of record/playback heads and erase heads in tape recorders).

Understanding is what brings curiosity to rest (Peirce, 1878; Piaget cited in von Glaserfeld, 1970/1987), if only momentarily before further ideas and tests are generated. Dean had long sought to make sense of his technological world, *at least* from the age of two years (as volunteered by his grandmother). So, from early in our study, he was able to demonstrate his understanding of various technological devices, for example, by recognising the potential advantages of converging telephone and television technologies, by operating keyboards, monitors and mice of computers, by explaining what he had seen "inside a computer hard drive" and by fixing malfunctioning tape recorders. His understanding seemed to stem, in large part, from the richness of his own life experiences. For example, his family owned a wide range of technological things (e.g., telephones, personal computers, laptops, modems, printers, tape recorders, crystal radios, a wide variety of tools, various batteries, watches, still cameras, calculators, televisions and VCRs). These devices were available to him and he appeared to exploit their availability. Whilst he was often able to identify places where his understanding fitted with his world, there were times when he was able to discern where it might not. For example, he seemed certain about the working of CMOS batteries but sought further information as to what the battery might actually *look* like. There were many times when he was able to identify the kinds of further understanding he required. For example, over a nine-month period he struggled to deepen his understanding of microchips, discovering what they looked like, where they were positioned and how many of them were in computers.

Yet, when he commented, "I'd like to know what the microchips ***do***", he understood that he did not have some crucial information. So, he seemed to know what he knew *and* he seemed to know what he did not know.

In essence, underpinning Dean's exploring, designing, making, operating, explaining and understanding was the need to bring all his senses into play: sight (for example, he watched intently to see "if anything [came] out" of a cut piece of audiotape), hearing (for example, he held his ear close to a telephone microphone), touch (for example, he ran his finger over the smooth surface of the "signaller (record/playback head)" and the "feeler (erase head)" of a tape recorder), smell (for example, he smelt what he called the "sort of battery smell" of the contents of a battery) and taste (for example, after a slight electric shock, he commented on the sweet taste of his cup of tea).

So, this *Meno* question provided a useful way of identifying not only a young learner's methods of inquiry but as well distinctive features of them. By exploring, by designing, by making, by operating, by explaining and by understanding Dean naturally inquired into his subjects. His inquiring seemed to be born out of the sum total of his life experiences: He seemed to be skilled in selecting methods of inquiry likely to provide the insights he needed.

5.1 The *Meno's* Question (3): Whether Dean Learned

The *Meno's* third question confronts the central educational issue of whether such inquiring constitutes learning. Dean's inquiry appeared to provide evidence of three kinds of learning: empirical, analogical and philosophical. A single example of each follows.

In his first visit to Robin's home Dean explained, "I've got a calculator – it's solar-powered." Two months later, he added, "When you cover all its power cells with your hands, it won't go off 'cause it's electronic as well". Unbeknown to us Dean persevered in his investigation of calculators. Five months later, he excitedly rang to tell Robin what he had discovered, saying,

> I find with this calculator (grabbing in a little breath) – it's a solar-powered one – (still holding the handset of the telephone, he reached to pick up his calculator, saying) when I press the button, it *didn't work*! I pushed it all over the place [in various positions] – and it worked! But in the *shade* – it didn't work! When I pulled it out of the shade [and put it in the sun], it worked again!

Insights he had gleaned earlier by using his hands to cover the panel had apparently not sufficed. He had needed to see for himself the effects of light and shade (that is, 'blocked' sunlight) on the working of his calculator. Now, he had his answer. Empirical testing gave *Dean* a way of discerning what he had not previously know. Furthermore, his generating and testing of ideas as he used this mode of inquiry allowed *us* to identify the progression in his ideas.

Often Dean used a form of analogical exploration, based on the assumption that if two things are known to be alike in some respects, then they must be alike in other respects. His handling of devices allowed him to reason analogically as to how unfamiliar devices might work. So, he considered how a solar-, battery-, dynamo-powered radio/torch might work in terms of his understanding of telephones. He extended the aerial and wondered whether it might make a difference to the sound. He then weighed his findings by what he had earlier observed in his telephone, explaining,

> Our cordless telephone can do that. You can have [the aerial] down and you can still speak just as the radio continues to play whether the aerial is up or down ... I think it's like a radio ... It gets signals – from the radio station. You know, we can go 100 metres and can still ring people!

The fluidity of his ideas and the fluency with which Dean was able to express them served to highlight his satisfaction with his analogies. It was as if he had been able to articulate, analogically, something he had not previously known. By so doing, we, too, were able to know that his ideas had deepened.

Dean's questions were often an invitation to philosophical reflection. When the storing of sound information puzzled him, he attempted to draw Robin into inquiry, musing,

> I wonder how the melody *does* it ... What does it *do*? ... When – like – it's *done* (the computer is closed down) – what would it do – just say – when you go out of the computer ... When you've clicked out of it ... You click 'OK' then it comes up on the monitor – but what would it do with the *melody*? ... What does it *do* with it?

When this question continued to puzzle him two weeks later, he rang to see whether a colleague with expertise in computer technology might be able to shed some light onto it. He requested,

> Could you ask him about what the melody *does*? ... I mean – what does it actually ***do*** ... What's it to do with the *turtle*? ... But what does it ***do***? What does the melody ***do***? ... like what does it do – like – with make it – when you *do* something the turtle? Does the turtle – like – *play* when you [type in the notes]? Maybe you've got to do some special way – or say, 'Play Melody' or something. Woo! It would be good – [if it did what we told it]! *But* the turtle's the slave! What you order it to do, it does! Yes (tentatively) – he *couldn't* just put the pen down to write – *and* play melodies ... It can sort of – think – but it doesn't know *all* that we do – we're the *brain* – it's the slave ... It can't know what to do [unless we tell it].

In the process of mulling over the question for himself, Dean became what Kohanski (1998) termed "the philosophical programmer", expressing ideas which resonated with Kohanski's explanation of computer programs: "a program is a set of detailed instructions given to a computer to perform a specific task. The computer will take no action without such instructions ... [It] will do nothing on its own ... A computer does nothing unless we give it orders" (p. 10). Through his deep philosophical urge to understand the nature of things Dean was able to recognise that his ideas had deepened, and his conversations allowed us to recognise his learning, too.

So, the third *Meno* question revealed this young learner's ability to learn by his own efforts. Empirical, analogical and philosophical tests of his ideas affirmed his understanding for himself, as well as for us, and even more significantly, showed him what he still needed to know.

6 Implications

We began this paper by highlighting the culture's expectation that its young people will generate technological advance in their time. We argued that much of our knowledge about the development of young children's technological capability is based on studies of their responses to teacher-developed curricula. Young children's own efforts to learn about their technological world appeared to us to offer a fruitful research domain for understanding the development of technological capability. To that end, we investigated how one young child's ideas about phenomena developed over time, within his technological culture when he instigated and pursued his own inquiry. We suggested that such findings might have significant implications for teacher education in the current information age.

To assess the educational significance of this child's technological narrative, we developed a framework based on answering the three *Meno* questions. First, we assessed the alignment

between the culture and the child's subject choice. Then, we identified the child's methods of inquiry. Finally, we examined empirical, analogical and philosophical evidence of learning.

This two-year single case study provides direct evidence of the educational significance of one young child's own technological inquiry and demonstrates the effectiveness of our framework for gauging the educational significance of what he did. In these two ways the findings of this study provoke consideration of teachers' control of the content and the process of classroom curricula. In this study, curriculum was generated as Dean, his family and members of his community developed it together in their everyday lives, at every opportunity. These findings demonstrate that teachers need not be solely responsible for directing and controlling curriculum. Rather, as "cultural anthropologists" (after Papert, 1980, p. 181), they can fruitfully exploit the resources of the child's community in fluid and opportunistic ways; and the assessment framework developed and successfully demonstrated here directly addresses challenging questions about how the significance of such learning might be judged.

Such radical rethinking of curriculum and assessment require large shifts in educational cultures. Such shifts must become the responsibility of the teacher education sector if they are to be established, let alone thrive, beyond it; and it is no simple matter to address them with integrity in professional formation. We suggest that teacher educators consider adopting similar curricular structures for prospective teachers as learners, as a way of assisting them to appreciate the worth of learning as curiosity-driven inquiry. We have pioneered a model of such a subject over the past seven years at the University of Technology, Sydney. Our undergraduate Educational Research subject, a prerequisite subject for intending honours students, is also popular with the student cohort at large. This subject nurtures students' refinement of significant educational questions and assists them to prepare, conduct, describe, analyse and report their own ethically sound, well-planned investigation. Students report how powerful the experience is for them. It prepares them for subsequent research, but also deepens their understanding of learning and teaching and imbues them with the confidence that comes from successful, self-directed inquiry and the development of obvious expertise in a field of their choosing. Their presentations and reports substantiate, to them and to us, the educational worth of this curriculum structure. We think that such small, but innovative rethinking of teacher education in line with the findings of the present study, could fruitfully be extended beyond the provision of one subject so as to reconceive teacher education as an opportunity to elicit and cater for students' concerns, interests and needs, alongside serious consideration of educational system priorities.

Such rethinking, to meet the challenges this investigation poses for teacher education, is in tune with current movements in the culture towards lifelong learning. It suggests adopting a different style of learning, both in teacher education and in the many educational contexts in which teacher education students will find themselves, one characterised by such as,

Learner-directed inquiry, using the etiquette of everyday conversations,

Unspecific content, selected for its personal and cultural worth,

Spiral curriculum, with its emphasis on the intuitive grasp and use of ideas and its ability to return to these ideas at higher levels of schooling (Bruner, 1960),

Many agencies, in the local community and beyond,

Independence of time, in and out of school hours and

Contemporary and future oriented contexts.

Clearly, for such curricula to flourish, teacher educators and teachers themselves will need to be convinced of the integrity of an alternative assessment strategy, one that is not dependant on our ability to set content a priori. The analytical framework developed here appears to provide a new and significant basis on which children's technological capability can be assessed even when curriculum is individual and unanticipated – and such assessment can be undertaken by teachers, by parents and, importantly, by children themselves. As such, the work constitutes a novel, domain-specific contribution to the educational debate surrounding conventional modes of assessment, typically being discussed generically in terms of norm-referenced or criterion-referenced testing and sets of competencies. Here at least, in the early development of technological capability, it appears to be educationally powerful to conceive of learning in terms of "being technological" and to examine the nature of children's *naturalistic* pursuits *over sustained time* and the extent to which they are aligned with authentic technological work within the culture. Indeed, Dean appeared to have a view of technology that acknowledged progression and development of purpose, design and use of ideas in cultural contexts. In this way, he demonstrated what Jarvis and Cosgrove (1994) termed, an "authentic view of technology" (p. 10). Such evidence is at odds with early studies of children's views of technology conducted by means of direct questionnaire (e.g., Rennie and Jarvis, 1995). It suggests the worth of a children's curriculum for developing broad views of technology (after Jarvis and Cosgrove, 1994). There is hope here, in at least this young child's views, of developing *broad* ideas about technology, overcoming a long-standing and significant obstacle to systemic reform in technology education (see Hall and Schaverien, 2001).

It was Ausubel (1968) who wrote that tenacious loyalty to existing ideas makes it difficult for people to unlearn. The present study goes some way towards providing an empirical description of how the preconceptions Ausubel described might become established through early experience. For this child, technological ideas deepened as he made his own connections. There seemed to be seamlessness to his inquiries: his subjects often came serendipitously and formed a complex web of connections – as he actively exploited the resources of his home and community. In this regard, the study begins to show how even very young learners can and do successfully appropriate for themselves the role teachers have conventionally played, and how teachers might usefully nurture such independence, collaboratively with children's communities so as to hedge the chances of developing wise and capable technologists in the next generation.

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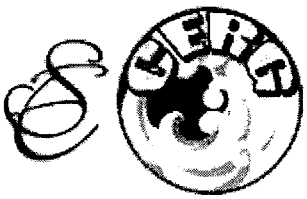

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