Southern Cross University
ePublications@SCU

School of Tourism and Hospitality Management

2004

Capacity for abstraction and the applied technology learner

Kurt W. Seemann
Southern Cross University

Publication details

Post-print of Seemann, KW 2004, 'Capacity for abstraction and the applied technology learner', in H Middleton, M Pavlova & D Roebuck (eds), *Proceedings of Learning for Innovation in Technology Education: 3rd biennial International Conference on Technology Education,* Surfers Paradise, Qld., Centre for Learning Research, Griffith University, Nathan, Qld. vol. 3, pp. 101-106.

ePublications@SCU is an electronic repository administered by Southern Cross University Library. Its goal is to capture and preserve the intellectual output of Southern Cross University authors and researchers, and to increase visibility and impact through open access to researchers around the world. For further information please contact epubs@scu.edu.au.

Later Published by
Learning For Innovation in Technology Education
Centre for Learning Research
Griffith University, Dec 2004

DEST Blind Refereed Paper
Dr K Seemann, Southern Cross University

Capacity for Abstraction and the Applied Technology Learner: Implications of Fluid Intelligence and Mental Rehearsal Research for Innovation Education (DRAFT)

Abstract
This paper provides a summary of contemporary Australian and international research that connects for the technology educator new understandings for developing the capacity for abstraction and its links to innovation education for the technology classroom. Associated with Fluid Intelligence, the capacity for abstraction is claimed to be the most developing intelligence observed world wide with each new generation showing greater capacities than the previous one (Flynn, 1994, 1999). Similarly new research linking mental practice for enhancing physical performance offers insight into an untapped area for the technology teachers interested in enhancing innovation capacities of learners (Cooper, Tindal-Ford, Chandler, & Sweller, 2001). Implications for pedagogy are discussed.

Introduction
The move towards a more innovation and knowledge driven society demands much better problem solving and adaptive thinking skills applied in various technological areas. The most recent brochure distributed by the Australian Academy of Technological Sciences and Engineering (ATSE) is in accord with the new mental performance demands now placed on technologists.

> "Technology education is an essential part of schooling because it is the place in the school curriculum where students get the opportunity to concentrate on developing creative and innovative ideas and then on testing these ideas in a practical context. It is not just about making things. It could be about designing the governance of Australia as a republic…The importance of design and thinking skills that are fundamental to technology education have not necessarily been the foundation of …long-standing programs." (Australian Academy of Technological Sciences and Engineering, 2004).

Educators can be forgiven for interpreting the move towards the knowledge and innovation age as a move towards more classroom theory (thinking work) at the expense of skill performance development in the mastery of hardware and software tools. This paper summarises emerging research that suggests a counter-intuitive understanding of how thinking skills can yield better motor skill performance than just manual drill and practice in the applied use of tools and instruments.

Innovation capabilities, abstraction and fluid intelligence

A new demand on the development of the technological mind

The Department of Education, Science and Training (DEST) has named innovation as the central role of technology curriculum designers and technology teachers. This role highlights some new dimensions to the technological experience and performance on tasks. Teachers are expected to model innovation and foster an array of contemporary skills.

> "At all levels, our society will require creative individuals able to communicate well, think originally and critically, adapt to change, work cooperatively, remain motivated when faced with difficult circumstances, who connect with both people and ideas and are capable of finding solutions to problems as they occur" (Department of Education Science and Training, 2003, p. 5)

Most of the above rhetoric should be familiar to most technology teachers. However, two key clauses stand out as unusual for the Federal Government label as a capability to develop. These are "remain motivated when faced with difficult circumstances" and "are capable of finding solutions to problems as they occur". Both these clauses relate to the ability to adapt to new knowledges more readily and openly, otherwise known as general Fluid Intelligence.

Fluid Intelligence is defined as our "on-the-spot reasoning ability, a skill not basically dependant on our experience" (Belsky, 1990, p. 125).

The intention to develop more capability in innovation both in the use of technologies and especially in the development of solutions through better thinking skills raises new teaching method opportunities not historically dominant in many technology classrooms.

Two skills are of particular interest to this paper:

1. The capability of finding solutions to problems <u>as they occur</u>, and
2. The capability of <u>enhancing motor performance through better thinking</u> and mental imaging skills.

It will be suggested that the first skill noted above challenges teachers to place more focus on teaching strategies that foster the effective use of fluid intelligence: that capacity to abstract solutions as they occur where the content of the variables to the problem (and so solutions pending), are not well associated with historical knowledge or established and trained skills: the need to be able to design first and establish which manual skills may be needed second. We can contrast problem solving that demands fluid intelligence with problem solving that demands crystallised intelligence. It is asserted most technology teachers are well acculturated in teaching students how to draw on their crystallised intelligence where typically the teacher assumes a student must be 'filled' with tool and technique skills before they are capable of creatively developing solutions to tasks set: the need to predetermine the solution by assuming required manual skills first before a designed solution is developed. Fluid intelligence is well placed for innovation development; where as crystallised intelligence is traditionally placed for crafted production.

It will be suggested that the second skill noted above challenges teachers to place more focus on teaching strategies that foster the effective use of vivid thinking and imagining skills. Not to create passive philosophers (though this may also need to be enhanced in certain tasks), but to tap into new cognitive learning theory research that suggests students will perform motor skill (manual applied tasks) better and learn it more efficiently if they are required to mentally practice imagining the task being executive by them before they actually execute the task. Historically, many teaching styles of technology teachers focus on filling most of the hours of learning with manual drill and skill practice and little time placed on mental thinking skill practice. Often this is reduced to 'passive theory' classes, though even in these classes it may be questionable whether good mental development is actually being taught!

Imagining and motor performance

Perhaps associated with the seduction of ordinary experience, most technology teachers would agree that the best way to teach practical performance skills (psychomotor skills) is through a lot of physical 'hands-on' practice. Thinking skills are often treated in the curriculum as a non-performance skill where the learner, more or less, sits passively before a teacher and gets 'practical' only to the extent they may be asked to discuss a topic or write on a topic including write answers to a given question.

Recent cognitive learning theory research by Cooper (2001) and others claim that not only can mental imaginings enhance practical skill performance, but that to achieve mastery of motor performance in a practical task, more physical practice may actually hinder improvement of performance whereas more mental practice can further advance practical performance. Further, the more cognitively complex the execution of the skill becomes (for example learning to operate a musical instrument or learning to use a CAD software program), the more mental passive rehearsal improves actual applied performance. That is, the more knowledge driven the motor task is, the more thinking practice becomes a key determinant of how well the skill is executed in practice. What is more, according to Cooper (2001), is that manual drill and practice seems to show a limit in its effectiveness for improving task execution particularly as the learner approaches a more expert level of general skills.

The case for enhancing motor skills through stronger use of vivid imagination (practice the thinking work)

Mental rehearsal is an establish method for increasing practical performance in sports psychology, usually applied in the expert end of skill performance. It is relatively new to see its application in ordinary motor skill development tasks like learning to use a clarinet, using equipment well or learning to use a 'tool intensive' computer application like CAD (Chandler & Sweller, 1996; Cooper et al., 2001; Greenfield, 2004).

To understand how mental rehearsal and practiced imagination improves motor skill development, one has to appreciate the link between how our neural system is thought to develop automated schemas and how improved neural links relate to improved motor performance.

In lay terms, our brain works better at doing physical tasks the more it is engaged in imagining those tasks in a very deliberate, vivid and focused sequence of imagined actions: the mental image to do this is associated with the idea of our brains having developed a 'schema' to manage our thinking. A well developed schema means we can

automate much of the execution of performance to a high standard. When we learn to drive a car, our brains eventually form well connected links (biologically) and when these links are sufficiently developed (biologically) our conscious efforts to execute a task is faster. This is thought to be the case because responses are being handled by the subconscious much more efficiently by the schema formed there in long term memory. These schemas are also associated with culturally learned intelligences otherwise referred to as the formation of our crystallised intelligence. We eventually drive our car with little conscious regard for what all our many motor actions need to do to effect task execution well.

In lay terms, the conscious brain is a slow processor and has limited 'buffer' to hold task information. The subconscious part of our brain is a faster processor with higher memory capacity. The sign of successful learning is associated with the ability for the subconscious brain to rapidly execute the desired performance in a largely automated way. Much like a guided instruction to a massive subroutine processor that can draw on a developed schema for the task.

There is no absolute claim being made in the literature, that all one needs to do is 'think' about a skill procedure to then be able to perform it well. There is a claim, however, that if thinking is more purposeful, vivid and mentally practiced, that motor performance can, in certain situations, be better executed than manual practice and that the latter has a limit in its effect on improving motor performance (Cooper et al., 2001). More manual practice has a limit in its effectiveness.

Better thinking improves motor performance, according to Cooper (2001), after some basic practical experience with the task and is especially enhanced the more knowledge intensive the motors skill (or task) becomes. Thus, lifting a weight is a low knowledge intensive motor task and here mental rehearsal has little impact. Using a computer application or a more sophisticated (knowledge driven) tool (like a musical instrument) does accelerate learning and motor performance. The more mental imagination practice is performed (whether or not actual practice is also performed during the rehearsal stage before testing the motor skills) (Cooper, Tindal-Ford, Chandler, & Sweller, 2001) the better the quality of the motor performance.

The role of working and long term memory to build knowledge schemas

Performance in a new psychomotor task can be superior to ordinary practice if approached with greater emphasis on mental practice: that is, on thinking <u>better</u> (Chandler & Sweller, 1996, p. 152). What is thought to be happening is that our capacity to perform tasks is related to the degree to which we have formed deep long term memory schemas. However, in the initial stages of learning, we load and often burden our short term memory and this load is felt as that stage of learning where it seems initially 'difficult'. The schema theory (Chi, Glasser, & Rees, 1982, p. 255) suggests the goal of instruction is to move quickly to assisting long term memory in forming schemas to accommodate motor performance. Learning has been successful when there is evidence of automated performance: more focus could then be afforded to the solution and less to the detail of procedures.

Conclusion

Implications for new Technology pedagogies to meet the demands of the innovation age

The work on how thinking practice actually improves motor skill performance in cognitive learning research is highly significant. A dominant feature of the innovation economy is that technologies used in production and development are increasingly much more knowledge intensive to operate or to apply to produce multi-element solutions to given briefs. There is either more cognitive demand to learn to use many modern technologies, or there is more cognitive complexity expected in the execution of knowledge driven tasks: more depth is expected in the quality of 'solutions'.

The role that 'better thinking' plays on motor performance opens a whole new domain of technology pedagogy. It offers interesting opportunities for developing one of the key capabilities of an innovator, that of rapid adaptive development to new psychomotor skills in technologies and the capacity to abstract knowledge from one domain and better practically apply it into another.

Mental imaging and rehearsal and fostering application of fluid intelligence: could these be the basis of the new pedagogies associated with innovation education in technology classrooms?

Mental Image rehearsal and Fluid Intelligence are suggested to be new areas for technology teachers to explore and exploit in the strategies they use in the classroom. Their likely application as strategies may be in the following contexts.

Mental image rehearsal: best where tasks (and so technologies to be used) are more demanding on cognition (more knowledge driven to operate effectively).

Fluid Intelligence: best where technologies are so advanced, the skills and knowledge required to use them are very simple and so more time can be spent on thinking through the quality of the innovation rather than labouring over manual drill and practice.

Bibliography

Australian Academy of Technological Sciences and Engineering. (2004). *Technology is really a way of thinking*. Parkville: Australian Academy of Technological Sciences and Engineering, and Leighton Holdings Limited, Victoria.

Belsky, J. K. (1990). *The Psychology of Aging Theory, Research, and Interventions*. Pacific Grove: Brooks/Cole Publishing Company.

Chandler, P., & Sweller, J. (1996). Cognitive Load While Learning to Use a Computer Program. *Applied Cognitive Psychology, 10*, 151-170.

Chi, M., Glasser, R., & Rees, E. (1982). Expertise in Problems Solving. In R. Sternburg (Ed.), *Advances in the Psychology of Human Intelligence* (pp. 7-75). NJ: Erlbaum, Hills Dale.

Cooper, G., Tindal-Ford, S., Chandler, P., & Sweller, J. (2001). Learning by Imagining. *Journal of Experimental Psychology: Applied, 7*(1), 68-82.

Department of Education Science and Training. (2003). *Australia's Teachers: Australia's Future. Advancing Innovation, Science Technology and Mathematics. Agenda for Action*. Canberra: Australian Government.

Flynn, J. (1994). IQ gains over time. In R. J. Sternburg (Ed.), *Encyclopaedia of human intelligence* (pp. 617 - 623). New York: MacMillan.

Flynn, J. (1999). Searching for justice: the discovery of I.Q. gains over time. *American Psychologist, 54*, 5-20.

Greenfield, S. (2004). *Baroness and the Brain*. Retrieved 26 August, from http://www.abc.net.au/catalyst/stories/s1185573.htm