

Future focussed pedagogies and learning approaches

“The future is already here – it's just not evenly distributed.”

William Gibson, The Economist, 4 December 2003

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# Introduction

In this paper we begin from the assumption that *a* purpose (not necessarily *the* purpose) of school education is to assist students to live and work successfully at school and beyond it. Part of this purpose is to assist students to successfully meet the social, economic, technological, health and ecological challenges they are likely to face in their lives. In seeking to realise this purpose, it needs to be recognised that schools are *future-makers.* Whether they plan to or not, schools shape the future.

In this paper we identify a number of challenges that are significant now and are likely to be in the future. We identify a range of capabilities that are necessary to successfully meet these challenges. Next we examine those pedagogical practices and approaches that are necessary to cultivate these capabilities, and the technological, assessment, spatial, temporal and policy arrangements that best support these pedagogical practices. While the audience for this paper is primarily policy makers, and is intended to provide evidence to inform the Department’s pedagogical policies, it may also be of interest to teachers and school executives.

The research questions for the paper are:

* What is the range of effective pedagogies available for cultivating general capabilities necessary for success in life and work in the future?
* What are the characteristics or features of these pedagogies? How can they be classified?
* What is the evidence (if any) for the effectiveness of these pedagogies?
* What is the role of technologies in supporting learning using these pedagogies?
* What is the range of the assessment tools that support and complement learning using these pedagogies?
* How can learning spaces be best developed to support learning using these pedagogies?

## 21st Century Challenges

Early in the 21st Century we face a number of challenges or *change imperatives* that are significant now and in the medium to longer term. These challenges include:

1. social challenges - such as maintaining and improving the vitality of a democratic society ([Nussbaum, 2010, p. 26](#_ENREF_31))
2. economic challenges - such as preparing ourselves for employment in jobs that do not yet exist, creating ideas and solutions for products and problems that have not yet been identified, using technologies that have not yet been invented ([Darling-Hammond, 2011, p. 2](#_ENREF_12))
3. technological/Scientific challenges - such as preparing ourselves for the increasing power of, and dependence on, science and technology; information overload; and increasing global integration ([Gardner, 2010, pp. 7-8](#_ENREF_20))
4. health challenges - maintaining and improving our physical and mental health
5. ecological/environmental challenges- finding ways to live and work that are less harmful to living systems ([Stevens, 2012](#_ENREF_39), [2015](#_ENREF_41)).

## General capabilities

What capabilities or skills are necessary to address these challenges? The Australian Curriculum Assessment and Reporting Authority (ACARA) has identified seven general capabilities as a key dimension of the Australian Curriculum. They encompass the knowledge, skills, behaviours and dispositions that, together with curriculum content in each learning area and the cross-curriculum priorities, will assist students to live and work successfully in the twenty-first century. These are:

* Literacy
* Numeracy
* Information and communication technology
* Critical and creative thinking
* Personal and social
* Ethical understanding
* Intercultural understanding ([ACARA, 2013](#_ENREF_1)).

These capabilities are not the only general capabilities that might be usefully cultivated in schools. For example, leadership and entrepreneurship may be seen as crucial capabilities for success now and in the lifetime of learners currently at school. Holistic thinking – understanding how the whole influences and shapes the parts – is a vital capability to meet the ecological challenges of the 21st Century ([Stevens, 2012](#_ENREF_39), [2015](#_ENREF_41)).

## How can general capabilities be cultivated?

Barron and Darling-Hammond ([2010](#_ENREF_3)) claim that in order for these capacities to be nurtured students must be given opportunities to develop them in the context of complex, meaningful projects that require sustained engagement, collaboration, research, management of resources, and development of an ambitious performance or product. They refer to research demonstrating that students do not routinely develop the general capabilities from working on more constrained tasks that emphasise memorisation and call only for responses that demonstrate recall or the application of simple algorithms.

## Teaching and Learning as Work

Recognising that teaching and learning is work, for teachers and students alike, and that the education industry involves the division of labour ([Connell, 1985](#_ENREF_11)), allows pedagogies to be seen as tools to achieve the goals of education.

New pedagogies should focus on the relationship between students and teachers in a proactive learning partnership to promote a balance between the teacher’s role as a "guide on the side" and the "sage on the stage" ([Fullan, 2013, p. 25](#_ENREF_18)) – the spectrum of student-centred and teacher-centred philosophies. This is a *work* partnership, one in which "student labour"involves students helping teachers with technology, helping fellow students as co-learners, and helping themselves by taking on a greater share of learning as partners.

All pedagogies make use of student labour, by assigning to students varying roles in their learning, even if it is reading and listening. Seeing students as workers is a useful perspective in relation to debates about equipping students in classrooms with tools such as laptops and ergonomic working spaces, just as adults rely on these tools and spaces to achieve their own work ([Goodyear, 2011](#_ENREF_21)).

To suggest that teaching and learning is work is not to suggest that learning should not be pleasurable, exciting, challenging, involve testing hypotheses and mimicking others. Neither learning, nor other forms of work, need be drudgery. Seeing learning as work is to emphasise the relationality and sociality of learning. It also provides a lens for understanding the ways that different pedagogies divide labour between teachers and students to achieve the goal of learning. Differing pedagogies can be seen as differing combinations of labour.

Pedagogies, then, can be understood as a particular combination of labour between teachers, learners and technology in which specialised skills, tools and production operations are combined into an organised system.

Knowledge (including know-how) is generated by these combinations of labour in which people and their learning tools engage in relational strategies within networks that are spread across space and time (Fenwick, Edwards, & Sawchuk, 2011). The main point of classroom work is for students to pose questions, work collaboratively to solve problems, theorise, read, write, experiment and discuss to create or modify public knowledge — knowledge that lives ‘in the world’ and is available to be worked on and used by other people (van den Broek, 2012, p. 22).

Teachers and school students are generalist knowledge workers. To work effectively they have similar technological, spatial and temporal requirements as other knowledge workers.

## Pedagogies as combinations of learning activities

People learn though the following activities: reading; writing; listening; discussing; experimenting; modelling; designing; making. Pedagogies can be seen to consist of combinations of these learning activities, and can be distinguished by the activity they give emphasis to. An activity centred approach to the design and analysis of learning situations views activity as a mediator between tasks, tools and resources, interpersonal relationships and learning outcomes ([Goodyear & Carvalho, 2014](#_ENREF_22)).

# What is the range of effective pedagogies available for cultivating general capabilities necessary for success in life and work in the future? What is the evidence (if any) for the effectiveness of these pedagogies?

A common distinction is made between direct, teacher-centred, instructivist pedagogies on the one hand and inquiry-based, student centred, constructivist pedagogies on the other hand. We will call the first family of pedagogies *direct*, in that they are built around problems with clear, correct answers that can be learned quickly and the second family *inquiry-based,* in that they are associated with the teacher facilitating students’ own inquiry.A third family is metacognitive pedagogies, in which students learn to “thinking about thinking”.

## Direct pedagogies

The family of direct pedagogies includes those in which the teacher provides explicit instruction. These pedagogies tend to position the teacher as the director of learning where they communicate extensively with students, typically through lectures – the traditional if not always effective way to speak to large groups of students. Yet the best teachers typically do not read aloud from notes. They profess, stimulate, provoke and respond to student interest ([G. Davis, 2010](#_ENREF_14)). Included within this category are also technology-enabled pedagogies.

### Direct Instruction

An example of a direct pedagogy is Direct Instruction. Direct Instruction aims to accelerate learning through clear scripted direct instruction by the teacher and scaffolded practice aimed at student involvement and error reduction ([van den Broek, 2012](#_ENREF_43)). Direct instruction involves a combination of labour between teachers and students. The teacher provides clear and concise direct communication, a clear sequencing of content and guidance. Students, for their part, listen to the communication by the teacher, remember the content of what is communicated, and practice what they have learned. The clear and concise direct communication by the teacher may be conveyed through the medium of chalk/blackboard, pen/whiteboard or an electronic whiteboard. The student may take notes or practice a skill or concept through a medium of pen/paper or a laptop computer.

The Direct Instruction teaching program has repeatedly been shown to improve different learning outcomes including reading and mathematics. However, its prescriptive nature and the dominant role of the teacher in enacting the pedagogy is a common source of controversy ([van den Broek, 2012](#_ENREF_43)).

## Inquiry-based pedagogies

Successful inquiry-based pedagogies require problematisation of knowledge, and conveying norms for collaboration. This includes:

* subject matter can be problematised by encouraging students to define problems and treat claims and explanatory accounts, even those offered by “experts,” as needing evidence
* the teacher should encourage students to question all sources
* rather than ignoring differences across sources, the teacher can draw attention to them and encourage them to look for converging sources
* students can be given authority to address disciplinary problems by personally identifying them with claims, explanations, or designs in ways that encourage them to be authors and producers of knowledge
* the teacher can communicate an enthusiasm for debate and productive conflict
* public performances like presentations can encourage the ability to adopt a particular perspective as well as attention to quality
* students should be encouraged to address others’ viewpoints even if they disagree
* disciplinary norms, such as paying attention to evidence and citing sources, should be modelled and nurtured
* the teacher can encourage the students to incorporate a wide range of sources into their research
* students can also constantly be made aware of the requirement that they help their group members learn ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

### Socratic Pedagogy

One example of Inquiry-based pedagogy is Socratic Pedagogy. Matthew Lipman developed and refined a dialogue-based inquiry approach to teaching critical thinking called Philosophy for Children– a paradigm example of Socratic pedagogy. The approach is based on a ‘community of inquiry’ in which children learn critical thinking by listening to one another with respect, working with one another, building on one another’s ideas, challenging one another to supply reasons for otherwise unsupported opinions, assisting each other in drawing inferences from what has been said, seeking to identify one another’s assumptions and suggest alternatives ([Lipman, 2003, p. 20](#_ENREF_27)).

An example of such an approach is the 2010 trial of Ethics classes in New South Wales, Australia. Lessons were designed for a process of discussion-based inquiry, in which students engaged in discussion of ethical issues, guided both by purpose-built thought provoking teaching resources and questioning from the teacher. The lesson topics were Fairness, Lying, Ethical Principles, Graffiti, The Use and Abuse of Animals, Interfering with Nature, Virtues and Vices, Children’s Rights and The Good Life.

The lessons operate in the following way:

1. Ethical scenarios are transcribed onto cards and distributed, one to each group of two to three students.

2. Students engage in discussion of their scenario within their group and then declare their position, by placing the card on an appropriately marked place on the floor. (Where there is disagreement within the group or where all members of the group are unsure how to judge their scenario, the card is placed separately, at a place marked by a question mark).

3. Groups give reasons for their decisions about the placement of the cards.

4. Members of the class discuss the various placements and explore their disagreements. Discussion rules include the use of a Speaker’s Ball, possession of which confers the right to speak

5. Members discuss general principles underlying their reasons and which principles are more important than others.

Successful participation in dialogue-based inquiry – learning by discussion – involves exercising general capabilities such as critical and creative thinking, personal and social capability and ethical understanding ([Knight, 2010](#_ENREF_26)).

There is a body of evidence for the success of Socratic Pedagogies such as Philosophy for Children as summarised by Millet and Tapper ([2012](#_ENREF_28)). A meta-analysis of 10 studies that used controlled experimental designs found a 0.43 effect size on a range of norm-referenced outcome measures. These measures included reading, reasoning, cognitive ability, other curriculum-related abilities, self-esteem and child behaviour ([Trickey & Topping, 2004](#_ENREF_42)).

García-Moriyón, Rebollo, & Colom ([2004](#_ENREF_19)) conducted a meta-analysis of 18 studies that implemented Philosophy for Children for up to one year. The authors concluded that it led to an improvement of students’ reasoning skills of more than half a standard deviation, or 7 IQ points.

A meta-analysis that evaluated “thinking-skills programs” found that dialogical interactions generally promote the ability of children to transfer argumentation skills to different contexts. A 0.62 effect size was found for curriculum outcomes such as reading, mathematics, and science ([Higgins, Hall, Baumfield, & Moseley, 2005](#_ENREF_24)).

### Project-Based Learning

Project-based Learning focuses on student-designed inquiry that is organised by investigations to answer driving questions, and which includes collaboration among learners and others, the use of new technology, and the creation of authentic artefacts that represent student understanding. The “driving questions” are preferably ones of social importance (such as environmental issues) and the project work typically makes use of dedicated software, instrumentation, and data representation formats.

The Buck Institute for Education identifies seven essential project design elements for project based learning.

1. Challenging problem or question – an open-ended, student focussed “driving question” that focuses the task
2. Sustained inquiry
3. Authenticity – or “real world” – making the learning experience continuous with experience outside of the classroom
4. Student voice and choice
5. Reflection
6. Critique and revision
7. Public product – where a product can be a tangible thing, or a presentation of an answer to a driving question ([Buck\_Institute\_for\_Education, 2015](#_ENREF_9))

Most of these design elements are common to all inquiry-based approaches. The emphasis on authenticity and public product – learning by making or designing – are distinguishing features of project based learning. Philosophy for Children may involve children considering abstract philosophical questions removed from everyday experience – more theoretical than practical. Philosophy for Children may (but also may not) result in a public product.

Successful participation in projects bearing these design elements requires high levels of critical and creative thinking as well as personal and social capabilities (given that these projects are typically conducted in a community of inquiry).

### Learning-by-Design

An example of Project Based Learning is Learning By Design, a science learning program based on case-based reasoning models in which students design technology by using technology. Learning-by-design grew out of the idea that children learn deeply when they are asked to design and create an artefact that requires the understanding and application of knowledge. Design activity supports revisions and iterative activity as projects require cycles of *defining 🡺* *creating 🡺 assessing 🡺 redesigning*. The complexity of the work often dictates the need for collaboration and distributed expertise. A variety of valued cognitive tasks are employed such as setting constraints, generating ideas, prototyping, and planning through “storyboarding” or other representational practices. This pedagogy includes the programming and development of modelling and robotics products.

Barron and Darling-Hammond (2010) suggest there is a growing body of research indicating that students learn more deeply and perform better on complex tasks when they have had the opportunity to engage in “authentic” learning that is characteristic of Inquiry Based pedagogies such as Project Based Learning. They report that a set of studies has found positive effects on student learning of instruction, curriculum and assessment practices that requires students to construct and organise knowledge, consider alternatives, apply disciplinary processes to content central to the discipline and communicate effectively to audiences beyond the classroom and school. As an example, they cite a study of more than 2,100 students in 23 restructured schools that found significantly higher achievement on intellectually challenging performance tasks for students who experienced this kind of “authentic pedagogy” ([Newmann, Marks, & Gamoran, 1996](#_ENREF_29)). The use of these practices predicted student performance more strongly than any other variable, including student background factors and prior achievement.

## Metacognitive Pedagogies

Metacognition refers to “thinking about thinking”. It is the ability for students to plan, monitor, control and reflect on their work. This kind of approach is used in relation to solving complex, unfamiliar and non-routine (CUN) problems in mathematics, which are becoming increasingly important in innovation-driven societies ([OECD, 2014](#_ENREF_33)).

### IMPROVE

The IMPROVE model is designed for mathematics learning and has been used successfully in regular classrooms to incorporate socio-emotional aspects, adapted for other content areas such as science and used to structure teacher professional development programs. The stages include:

* introducing the whole class to the new material
* metacognitive self-directed questioning
* practising the metacognitive questioning
* reviewing the new materials using the metacognitive questioning
* obtaining mastery on higher and lower cognitive processes
* verifying the acquisition of skills
* enrichment and remedial activities.

They key element of IMPROVE is four types of self-directed metacognitive questioning that are about task comprehension (what is the problem about?); content connections (explain how the problem is similar or different to others?); strategic questioning (explain what the appropriate strategies for solving the problem are); and reflection (does the solution make sense? can it be solved differently? am I stuck?).

Substantial evidence has been cited in relation to the use of metacognitive strategies ([OECD, 2014](#_ENREF_33)). Of the metacognitive strategies covered, the IMPROVE model has been the most effective and useful for all learners.

In Kindergarten children IMPROVE enables better communication abilities, including richer explanations, expressions and verbal interactions with other peers. Children were also better able to plan ahead, generalise some principles about division, demonstrated a higher level of problem solving ability and self-efficacy. In primary and secondary school students, IMPROVE led to improved achievement in arithmetic and algebra. Specifically, primary students were better able to solve basic, as well as complex problems, and transfer their knowledge to new tasks. Secondary students showed similar gains as well as mathematical modelling, translating authentic real-life situations into mathematical expressions and finding patterns and generalisations. The effects are stronger with CUN tasks than with non-routine problems; it is argued that this is because CUN tasks cannot be solved without activating metacognitive processes, so explicit training in how, when and why one has to apply these strategies is crucial.

Most of the advantage of metacognitive teaching is at the beginning of schooling. Supposedly, equipping students with metacognitive strategies early on sets up effective learning behaviours that they continue to apply throughout their schooling. These long lasting effects are visible even a year after intervention has ended. Students continue to apply metacognitive strategies and continue to achieve higher than their control peers. Cooperative settings appear to be best suited to teaching metacognitive strategies, although this finding is variable.

## Pedagogies as simulating work

Teaching and learning is work. Pedagogies can be classified according to the way in which labour is divided or combined. Pedagogies simulate work outside of the learning context. For example:

* Direct Instruction simulates the work of a scribe, such as taking minutes or notes
* IMPROVE seeks to simulate the collaborative learning and reasoning of mathematicians and scientific theoreticians
* Project Based Learning seeks to simulate the collaborative learning and reasoning of designers of artefacts such as a computer animation piece, a play, a multimedia presentation or a poem
* Learning By Design seeks to simulate the collaborative learning and reasoning of an engineering laboratory
* Socratic Pedagogy seeks to simulate the collaborative reasoning of the parliament or parliamentary committee, or of a philosophical dialogue thoroughly examining the pros and the cons of a position, or perhaps public reasoning more generally.

## A Toolkit approach to pedagogy

The OECD states that to improve learning in school classrooms a balanced combination of both direct and student-centred instruction should be used.

While there is no consensus in the literature on which approach is better, an over-reliance on either approach is not recommended ([OECD, 2012, p. 138](#_ENREF_32)). Pedagogies are best understood as tools in a toolkit to facilitate student learning, provided that students have the basic knowledge and skills (best provided initially by direct instruction) before engagement in ‘rich’ inquiry-based-constructivist learning activities ([Rowe, 2006](#_ENREF_35)).

Recent research has put the most effective sequencing of learning activities into question by demonstrating that inquiry-based learning activities might usefully precede explicit teaching. “Productive failure" is a learning design intended to provide the conditions for learners to persist in generating and exploring representations and solution methods (RSMs) for solving complex, novel problems (Kapur, 2016). In Phase 1 students explore and investigate the affordances and constraints of RSMs. Phase 2 provides opportunities for organising and assembling the relevant student-generated RSMs into canonical RSMs through explicit teaching.

A literature review of inquiry-based approaches to teaching science and technology found that none of the approaches suppose that learners will ‘discover’ science and technology principles, concepts, practices, skills or processes. All require the teacher to provide explicit explanation at different stages of the teaching and learning and for them to either possess necessary knowledge to facilitate explanation or develop it as the teaching and learning sequence progresses ([Aubusson, Schuck, Ng, Burke, & Pressick-Kilborn, 2015](#_ENREF_2)).

We have seen that people learn through a variety of activities such as reading, writing, listening, discussing, designing and making. Different pedagogies consist of different combinations of these learning activities. This suggests that teachers should use a wide variety of pedagogies and assessments, involving a range of learning activities. Pedagogies should be treated as different tools in a toolkit.

# What is the role of technologies in supporting learning using these pedagogies?

As suggested in the title of the OECD publication Inspired by Technology, Driven by Pedagogy, the technology tail should not wag the pedagogical dog. Pedagogy should not be adapted to meet the affordances of new technologies. Rather, technologies should be adapted to support pedagogies.

We have seen that pedagogies are combinations of labour frequently involving technologies as tools for learning. These tools are integrated into the labour process.

Innovative learning environments by definition make use of a combination of pedagogical approaches that take full advantage of the possibilities afforded by teaching tools such as communication technologies ([Schleicher, 2015](#_ENREF_36)). An awareness of these affordances is key to the effective combination of pedagogies and technology.

In his recent book *The Evolved Apprentice* Kim Sterelny ([Sterelny, 2012](#_ENREF_38)) argues that “Human cognitive competence is a collective achievement and a collective legacy; at any one moment of time, we depend on each other, and over time, we stand on the shoulders not of a few giants but of myriads of ordinary agents who have passed on intact the informational resources on which human lives depend.” ([Sterelny, 2012](#_ENREF_38)). “Human cognitive competence often depends on epistemic engineering: on organizing our physical environment in ways that enhance our information-processing capacities…. Adaptive thinking depends on an adapted environment.” ([Sterelny, 2012](#_ENREF_38)). Tools generally, but information and communications technologies in particular, are an excellent means of epistemic engineering - seeding the environment in ways that enhance our knowledge, including know-how. The internet, and a search engine such as Google, are major pieces of epistemic engineering.

The use of remote technology is a way to resolve prohibitive logistics to be able to access resources that are peripheral in time as well as space for learning. For example, Astronomers require telescopes to do their work. The Faulkes Telescope Project, based in Parkes NSW enables the giant telescope to be available remotely for schools ([Faulkes Telescope Project, 2008](#_ENREF_16)). Particle physicists require access to the latest data from particle accelerators/colliders to do their work. The CERN Masterclasses make this resource available to schools ([International Particle Physics Outreach Group, 2016](#_ENREF_25)).

Computer-based tools can be useful in establishing ways of working and supporting productive collaborative exchanges. One of the best and most documented examples is the Computer-Supported Intentional Learning project that includes a knowledge-gathering and improvement tool to support inquiry and knowledge-building discourse ([Bereiter & Scardamalia, 2008](#_ENREF_4)).

### Design/Planning

Successful Inquiry-based approaches require teachers to have clearly defined learning goals, well-designed scaffolds, ongoing assessment and rich informational resources. It uses carefully designed activities that require diverse talents and interdependence among group members and the development of “group-worthy tasks” that are both sufficiently open-ended and multi-faceted that they require and benefit from the participation of every member of the group.

Design and planning can be facilitated by Program Builder – software that uses content from the new NSW syllabuses for the Australian curriculum to create scope and sequences and units and enables teachers to add their own teaching, learning and assessment activities, alongside content.

### Explicit teaching using a wiki to support inquiry

Barron and Darling-Hammond (2010) suggest that in Inquiry-Based approaches, teachers also provide instruction in more traditional ways such as providing lectures and explanation which are crafted and timed to support inquiry. Inquiry based pedagogies require careful balance. Teacher need to learn to balance students’ needs for direct information with their opportunities to inquire and to scaffold the learning of many individual students (providing enough, but not too much, modelling and feedback for each one).

Barron and Darling-Hammond (2010) suggest that students often neglect to use informational resources unless encouraged to do so and that to this end a wiki may be useful. This tool allows student users to freely create and edit Web page content via a Web browser. Through a wiki, the entire class of students can become totally involved in the creation and editing of a Website. This “open editing” encourages collaborative learning and democratic use of the Web and promotes content composition by non-technical users.

In addition, discussion can be facilitated through the use of clickers. Online tools specific to this purpose include Cohere and the Web-based Inquiry Science Environment, allowing teachers to design classroom units that require students to articulate, link and reflect on their own and peers’ ideas.

### Using digital technology to support combinations of labour in teaching and learning

Barron and Darling-Hammond (2010) suggest that a particularly important role for the teacher in inquiry based approaches is to establish:

* a range of activity structures – Some approaches assign children in the group to management roles, conversational roles or intellectual roles
* roles to support equal participation, such as recorder, reporter, materials manager, resource manager, communication facilitator and harmoniser.

Working in assigned roles could be supported by an app (or apps) that records and transcribes, allows access to "power point" or "prezi" for reporters, access to the internet and download capacities for materials and resource managers, social media for communication facilitators and an app that integrates these affordances for the harmoniser.

## Metacognitive

An example of an ICT-embedded metacognitive model is the Reflective Assistant which includes activities such as having students compare the solutions of previous problems with the current one, asking students to judge their learning and then providing them with data to reflect on the accuracy of their judgment, asking students to check on their progress to note trends and changes, and asking students to consider whether they have had the opportunity to solve similar problems in the past. When mathematics software includes metacognitive guidance it is found to lead to more effective academic outcomes than domain-specific mathematics software alone. Nevertheless, these ICT environments are not found to be as effective as a person providing the metacognitive scaffolding.

In developing student’s high-level cognitive skills, software can be used to remove cognitive load associated with tedious and concept-irrelevant auxiliary activities, such as drawing up a graph. Students can instead spend time focusing on the core of the problem such as analysing the outputs of graphing software.

Software can also support students working through a hypothesis-generation exercise, crucial to the solving of CUN problems by prompting them with scaffolds to allow them to construct complex plans for testing their assumptions on the basis of work that has been completed in the system.

In information acquisition technology (such as search engines, Wikipedia, and online databases), metacognitive resources can be provided in the form of guiding learners to organise the information, demonstrate how they might be able to relate the information to previous knowledge, judge their comprehension and plan to allocate resources to collecting as much information that is further required to answer the problem.

In the case of synchronous learning environments in which students are collaborating with others, students can be guided to articulate and formulate their thinking, reflect on their own and others’ ideas and communicate mathematically by being prompted explicitly to provide responses that address these areas ([OECD, 2014](#_ENREF_33)).

## Technology intensive pedagogies

Some pedagogies give a central role to information and communications technologies. Following are two examples.

### Learning by modelling - Computational scientific inquiry with virtual worlds and agent-based models

Sengupta, Kinnebrew, Basu, Biswas, & Clark, (2013) describes a unit of work that can be used to cultivate and assess computational thinking. The task involves modeling an ecosystem using NetLogo.

The task involves designing a simulation of a closed fish tank system consisting of fish, duckweed, Nitrosomonas bacteria and Nitrobacter bacteria. It involves designing a model of the entities and processes involved in the phenomenon using an agent-based, visual programming platform. A possible sequence of tasks could be:

1. Students begin with programming the behaviour of single agents in the ecosystem
2. Students gradually develop more complex programs for modelling the behaviour of multiple species within the ecosystem
3. Students gradually develop more complex programs for modelling the interactions between multiple species within the ecosystem ([Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013, p. 363](#_ENREF_37))
4. Students compare their model to an “expert” model of the phenomenon and adjust their model accordingly using data
5. Students program new agents – e.g. water snails – and re-test models
6. Students may apply the developed model and the learned science concepts in a new context.

The task requires a number of general capabilities such as:

* systematic thinking
* holistic thinking – particularly in steps 3,4,5 and 6
* critical thinking
* creative thinking ([Sengupta et al., 2013](#_ENREF_37)).

### Learning by making - TangibleK

Bers, 2010 notes that robotics provides opportunities for young children to learn about mechanics, sensors, motors, programming, and the digital domain. The approach invites young children to build their own robotic projects, such as cars that follow a light, or puppets that can play music ([Bers, 2010, pp. 1-2](#_ENREF_5)) TangibleK involves children making robotic artefacts and programming their behaviours. Children are required to keep design journals while creating robots. This helps make visible to the children, their teachers and parents their own thinking and their learning over time ([Bers, 2010, p. 6](#_ENREF_5)). TangibleK consists of seven sessions.

1. What Is a Robot? Children build their own robotic vehicles and explore the parts and instructions they can use to program them.
2. Sturdy building: Children build a nonrobotic vehicle to take small toy people from home to school.
3. The Hokey-Pokey: Choose the appropriate commands and put them in order to program a robot to dance the Hokey-Pokey.
4. Again and Again until I Say When: Students use a pair of loop blocks (“repeat”/“end repeat”) to make the robot go forward again and again, infinitely, and then just the right number of times to arrive at a fixed location.
5. Through the Tunnel: Children use light sensors and commands to program a robot to turn its lights on when its surroundings are dark and vice versa.
6. The Robot Decides: Students program their robots to travel to one of two destinations based on light or touch sensor information.
7. The Final Project: students design a robotic city, a zoo with moving animals, a dinosaur park, a circus, and a garden with robotic flowers responsive to different sensors. These final projects are shared in an open house for the wider community.

Session 3-7 in particular would require systematic thinking; each session involves some level of holistic thinking and creativity (in the sense of making something).

# What is the range of the assessment tools that support and complement learning using these pedagogies?

## Formative and summative assessment within a system of assessment

A distinction can be drawn between formative and summative assessment in that they seek to answer different questions about learning. Formative assessment is assessment for learning, as learning and of learning. Summative assessment is assessment of learning. Their implementation will differ by pedagogy, for example in an inquiry-based pedagogy, formative assessment will likely occur contemporaneously with teaching and learning by investigating the process of learning, and summative assessment may focus on the end product. A focus on process and task allows students to see cognitive prowess not as a fixed individual trait, but as a dynamic state that is primarily a function of the level of effort in the task at hand ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

Irrespective of the pedagogy it is important not to confuse the need for the thoughtful implementation and use of assessment. Neither replaces the other nor tells the complete story about a student’s learning.

Summative assessment complements instructivist approaches and is usually conducted at the conclusion of a unit of teaching. Formative assessment complements inquiry-based approaches, where assessment occurs contemporaneously with teaching and learning. In inquiry based approaches assessment can be an important part of learning.

Within summative and formative assessment there are a range of assessment strategies. These strategies should form part of a system of assessment: a continuum of options and methods for determining what students know and can do, which will offer different information to be used for different purposes ([Conley & Darling-Hammond, 2013](#_ENREF_10)). This continuum refers to the complexity of tasks, ranging from standardised multiple choice tests of routine skills on one end and longer and deeper investigations lasting several months, including exhibitions, portfolios or extended essays on the other. Tasks of increasing complexity and duration can measure larger and more integrated sets of knowledge and skills and provide insight into the application of learning to new settings.

High quality systems of assessments include:

* the assessment of higher-order cognitive skills, such as critical thinking and application of knowledge to new concepts
* high-fidelity, directly measured assessment of critical abilities, including communication (in its multiple forms), collaboration, modelling, complex problem solving, planning, reflection and research
* standards that are internationally benchmarked
* use of items that are instructionally sensitive and educationally valuable by reflecting concepts that are being taught and can be learned
* assessments that are valid, reliable and fair.

Assessment should be made to guide learning, by incorporating rubrics and public presentations, feedback can be given to students to ensure that this is made possible. Understanding student interests and aspirations through the development of a comprehensive student profile provides an indication of student career and university readiness which can be used to structure assessments as well as interpret their performance as a function of their personal motivation. Another advantage of the profile approach is that students are able to receive clearer guidance about where they stand in relation to university and career readiness to adapt their work accordingly.

Good assessment practices promote learning by providing multiple opportunities for feedback and through the use of student profiles that encourage a more holistic understanding of a student’s strengths, weaknesses and aspirations. Feedback seems to be more productive to the extent that it is focused on student process rather than product, and keyed on the quality of the work (task-involving) rather than quality of the worker (ego-involving) ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

Teachers make professional judgements about which assessment approach to use, when to use it, and how to modify it according to the context.

## Inquiry-based approaches to assessment

Barron and Darling-Hammond (2010) stress the importance of assessment in successful inquiry-based pedagogies – though they apply to all types of pedagogy. This includes:

* the design of intellectually ambitious performance assessments that define the tasks students will undertake in ways that allow them to learn and apply the desired concepts and skills in authentic and disciplined ways
* the creation of guidance for students’ efforts in the form of evaluation tools such as assignment guidelines and rubrics that define what constitutes good work (and effective collaboration)
* using formative assessments to guide feedback to students and teachers’ instructional decisions throughout the process
* providing guidance to students about the quality of work and interactions they are aiming for
* providing students with frequent feedback about their learning, especially when that feedback takes the form of specific comments that can guide students’ ongoing efforts ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

Barron and Darling Hammond suggest that successful inquiry-based approaches require planning and well thought out approaches to assessment. They argue that well-designed formative assessment and opportunities for revision support learning and well-designed summative assessments can be useful learning experiences.Formative assessment:

* provides guidance to students about the quality of work and interactions they are aiming for - clear criteria given in advance. The criteria used to assess performances should be multidimensional, representing the various aspects of a task rather than a single grade, and openly expressed to students and others in the learning community
* is a critical element in learning generally, and is especially important in the context of long-term collaborative work
* is designed to provide feedback to students that they can then use to revise their understanding and their work
* informs teaching so it can be adapted to meet students’ needs ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

The use of particular modes of assessment has benefits.

* exhibitions, projects and portfolios provide occasions for review and revision to help students examine how they learn and how they can perform better
* student presentation of their work to an audience – teachers, visitors, parents, other students can be an excellent way of learning. This approach to assessment can be used to assess students' mastery. Presentations of work, particularly public presentations, can signal to students that their work is significant enough to be a source of public learning and celebration. It can provide opportunities for others in the learning community to engage with student work.
* performances can embody representations of school goals and standards so that they remain vital and energising, and develop important capabilities. Good performance tasks are complex intellectual, physical and social challenges stretch students’ thinking and planning abilities while also allowing student skills and interests to serve as a springboard for developing capabilities. Use of performance tasks is also important to assess the benefits of inquiry-based approaches ([Barron & Darling-Hammond, 2010](#_ENREF_3)).

## SOLO

The Structure of the Observed Learning Outcome (SOLO) taxonomy ([Biggs, 1995](#_ENREF_6); [Biggs & Collis, 1982](#_ENREF_7), [1991](#_ENREF_8)), provides a systematic way of describing how a learner’s performance grows in complexity when mastering varied tasks. The SOLO taxonomy postulates five levels of increasing complexity in growth or development of concepts or skills:

* Prestructural: The task is engaged, but the learner is distracted or misled by an irrelevant aspect belonging to a previous stage or mode.
* Unistructural: The learner focuses on the relevant domain and picks up one aspect to work with.
* Multistructural: The learner picks up more and more relevant and correct features, but does not integrate them.
* Relational: The learner now integrates the parts with each other, so that the whole has a coherent structure and meaning.
* Extended abstract: The learner now generalises the structures to take in new and more abstract features, representing a new and higher mode of operation ([Biggs & Collis, 1991, p. 65](#_ENREF_8)).

Implicit in the SOLO model is a set of criteria for evaluating the quality of a response to (or outcome of) a task. The quality (or richness or complexity) of a response to a complex task varies with the relevance of the considerations brought to bear on the task, the range or plurality of those considerations, and the extent to which these considerations are integrated into a whole, and extended into broader contexts to create something new.

The SOLO framework can be used to assess the quality of a performance in a task. It can be used to assess the quality of an individual performance, the performance of a group working collaboratively on a task, and the contribution of an individual to a group performance. SOLO can be used to design learning and assessment tasks and sequencing of learning tasks from simpler to more complex. SOLO can be used to document a learning journey – identifying where a learner has been, where they are now, and where they might go next. It can also be said to make student thinking visible. SOLO can also be used as a framework for assessing the general capabilities ([Stevens, 2013](#_ENREF_40)).

# How can learning spaces be best developed to support learning using these pedagogies?

Learning spaces that best support learning using a variety of pedagogical and assessment approaches require the following features. They should be:

1. Open – to encourage freedom to move through space, and to encourage collaboration ([Department of Education and Early Childhood Development, 2011](#_ENREF_15)).
2. Varied – different types of learning spaces throughout the school, to support varied pedagogical and assessment approaches – and to support different learning needs of students ([A. Davis & Kappler-Hewitt, 2013](#_ENREF_13))
3. Flexible – e.g. furniture can be rearranged to create different kinds of learning spaces at different times
4. Integrated – technology needed to support pedagogies should be integrated into the learning space to encourage learning by doing ([Fisher, 2010](#_ENREF_17)).

Open learning spaces encourage learning by doing by encouraging movement rather than students always sitting still. Guldbaek argues that transforming a pedagogical ethos into an effective learning environment requires students being given opportunities to learn by doing, by participating and being *active* in the learning process. Learning requires playing, talking, walking, balancing, tasting and feeling. Open learning spaces can allow such interactive learning everywhere. Opening learning spaces – e.g. removing walls from classrooms, encourage greater sharing of space between teachers and students. This can encourage greater collaboration. ([Guldbaek, B, & G, 2011](#_ENREF_23))

Robinson and Robinson argue that the classroom design should demonstrate adaptability and flexibility. Furthermore, such design should emphasise stimulating, adaptable learning environments, with spaces to support various styles of teaching and learning. Pedagogical and physical structures need to be remodelled in parallel. ([Robinson & Robinson, 2009](#_ENREF_34))

Futurist David Thornburg identifies three archetypal learning spaces – the campfire, cave, and watering hole – that schools can use as physical spaces and virtual spaces for student and adult learning. ([A. Davis & Kappler-Hewitt, 2013, p. 24](#_ENREF_13)).

The campfire is a space where people gather to learn from an expert and suits more teacher centred and explicit instruction. The experts are not only teachers and guest speakers, but also students who are empowered to share their learning with peers and other teachers.

The watering hole is an informal space where people can share information and discoveries, acting as both learner and teacher simultaneously. This shared space can serve as an incubator for ideas and can promote a sense of shared culture. This sort of space supports inquiry based approaches.

The cave is a private space where an individual can think, reflect, and transform learning from external knowledge to internal belief. It also acknowledges the need for privacy and to be by ourselves sometimes. Most learners need some time to themselves, and some need more time alone than others ([A. Davis & Kappler-Hewitt, 2013, p. 25](#_ENREF_13)).

With flexible furnishings, e.g. chairs and tables that can be readily moved around the room or up and down, a campfire can be transformed into a watering hole, or into a series of caves.

Fisher discusses technology-enabled active learning environments. He examines technology-based active learning environments and suggests a blended learning matrix combining face-to-face physical and online learning. This is made possible through a variety of mobile communication devices. Fisher discusses the genesis of technology enhanced learning environments when it was introduced at MIT in 2003, that emphasises acoustics, furniture, lighting, mobility, flexibility, air temperature and security enhanced learning spaces ([Fisher, 2010](#_ENREF_17)).

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