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THE AUSTRALIAN CURRICULUM

Improving primary STEM education by integrating the Australian Curriculum

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Abstract
A report commissioned by the Australian Council of Educational Research in 2018 titled *Challenges in STEM learning in Australian schools: Literature and policy review* found that the Australian Curriculum is packaged in discrete disciplines and is not future facing. It concluded that "the goal is to see students working in an integrative way" (Timms et al. Australian Council for Educational Research, 2018, p. 2). Accordingly, this paper reports on the first phase of a design-based research (DBR) project which integrates learning around 28 specific learning outcomes from the existing Australian Curriculum. The hypothesis presented is that students and teachers can expand their knowledge and skills in STEM by having a daily STEM focus built into each day. As a longitudinal study, this paper reports on the initial planning and findings which continue to refine the theoretical assumptions of the DBR methodology. Given that the consultation phase of a major review of the Australian Curriculum ended on 8 July 2021, these insights also capture a pivotal moment in time. The three emergent themes which were evident across the 28 STEM units have the potential to collectively signal the essence and future direction of STEM education, namely science inquiry skills, data and variables, and design.

Keywords STEM · Integrating the curriculum · Design-based research · Translation of research

Introduction

The SILO project described in this paper is an acronym for Scientifically Integrated Learning Outcomes. It is also a play on words because education as a sector has often been criticised for teaching in silos where subjects are taught in isolation to each other. Historically, this has largely been the result of the institution nature of education where students physically move from one class to the next. The SILO project takes a different approach by using project-based learning to harness the learning outcomes within the existing Australian Curriculum which relate to STEM. The SILO project is a 3-year longitudinal study which has just completed the initial planning stage for 2021.

Primary schools have an inherent flexibility due to the localised nature of each classroom, but the timetable is generally still structured around clearly delineated blocks of learning such as literacy groups (2 h), numeracy (1 h), science once or twice a week and various specialist subjects. As the existing focus on literacy and numeracy is widely considered to be indispensable, any attempt to increase participation in STEM needs to enhance literacy and numeracy too.

There has been an international movement to increase student engagement and expertise in Science, Technology, Engineering and Mathematics since the US National Science Foundation started using the STEM acronym in 2001. Most attempts to boost the profile of STEM seek to integrate STEM into the curriculum. The acronym STEM is not in the Australian Curriculum as STEM content is spread throughout the component areas. The Technologies learning area covers Design and Technologies (i.e., engineering) and Digital Technologies (i.e., Information and Communication Technologies or ICT). "Engineering often provides a context for STEM learning" (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2016, p. 6).

The STEM Connections Project (ACARA, 2016) sought to integrate STEM learning in an Australian context. The origins of the project preceded the publication of the *National STEM School Education Strategy 2016–2026* (Education Council, 2015) but "it did address all the areas for action identified in the strategy, either directly or indirectly"

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(ACARA, 2016, p. 5). Perhaps the most significant findings from the *STEM Connections Project* related to helping to understand the challenges faced by both teachers and students. Students were reported to have often felt like they were lost in the new freedom afforded to them by project-based learning. For staff, the most significant challenge related to the open-ended nature of the various projects and "the need to surrender their role as leader of learning and subject expert to allow greater autonomy for students" (ACARA, 2016, p. 19). These issues are significant and not easily solved as they represent a fundamental shift away from how teaching and learning often occurs in schools.

Ironically, the biggest obstacle of all was the mundane but critical issue of timetabling and how to make room for innovative STEM projects "as timetabling structures do not necessarily have the flexibility to accommodate such projects" (ACARA, 2016, p. 20). The implementation plan for the current study addresses this concern directly by integrating other content areas into each project for one session each day. Careful cross-referencing has been done for all the learning areas for which a generalist primary school teacher is responsible to justify this use of time. It also presents a logistical framework to change how STEM education is implemented in primary schools by working within existing school structures and curriculum constraints.

The SILO project seeks to identify 28 STEM outcomes on which projects can built to embody learning throughout the primary years. It aims to address the most difficult issues directly, namely timetabling and the 'crowded curriculum' through integration using the design process. There are several variations of the design process, but the one adopted here is TMI (Think, Make, Improve) first proposed by Martinez and Stager in 2013. "Reducing the process to three steps minimises talking and maximises doing" (Martinez & Stager, 2019, p. 54). TMI is an example of the maxim to "make everything as simple as possible but not simpler" which is widely attributed to Albert Einstein. Children are unlikely to forget the three steps in TMI in contrast to existing design models which "may be too wordy or abstract for young learners" (Martinez & Stager, 2019, p. 54).

Although the SILO project attempts to address the international focus on improving STEM education, two of the research questions are about translation of research which is about bridging the gap between theory and practice. The three research questions are as follows:

1. How can project-based learning promote, sustain and embody an integrated STEM curriculum?
2. How can co-design of research between teachers and researchers be effectively undertaken to improve quality and usability of project findings and recommendations?
3. How does evaluation and translation of research best occur in classrooms and schools?

In the Australian Curriculum, the specific learning outcomes are referred to as "content descriptions". The Australian Institute of Teaching and School Leadership (AITSL, n.d.) refers to learning outcomes as 'learning intentions' to reflect the fact that there are no guarantees that students will learn what is presented. 'Learning outcomes' is the term used in this paper because this is still the most common language in Australian schools, and it is also part of the SILO acronym.

Research methodology

Design-based research (DBR) is a methodology specifically designed for interventions in educational settings "to increase the impact, transfer, and translation of education research into improved practice" (Anderson & Shattuck, 2012, p. 16). Barab and Squire (2004) are insightful here as "the validation of a particular design framework is not simply intended to show the value of a particular curriculum but results in the advancement of a particular set of theoretical constructs" (p. 9). The following five theoretical constructs embody the rationale for the SILO project in its current form:

1. The international emphasis on STEM is not likely to go away and will probably increase due to the rapid technological era in which we live.
2. "STEM education begins in primary school" (Prinsley & Johnston, 2015, p. 1).
3. Time is scarce in primary schools. This has led to certain phrases such as the 'overcrowded curriculum'.
4. The Australian Curriculum is essentially sound and useful, covering the necessary curriculum content for STEM education but within the component disciplines of science, technology (digital technologies), engineering (design technologies) and mathematics.
5. The challenge for teachers is to implement the Australian Curriculum in an efficient, equitable and authentic manner focusing on depth over breadth.

DBR is distinctive from other methodologies in two ways. Firstly, the design of the research constitutes a distinct source of data (Sandoval & Bell, 2004). The intrinsic flexibility of the methodology means that any refinements to the research methods are welcomed which helps ensure that the research objectives and results demonstrate high levels of alignment and useability. This also reflects the agile nature of STEM as a constantly evolving knowledge base.

Secondly, DBR often utilises conjecture mapping (Sandoval, 2014) where a hypothesis is clearly stated and then tested. Sandoval (2014) noted that there is no clearly identifiable set of methods that can be labelled as DBR and that the commonality is mainly in terms of certain commitments that include "the joint pursuit of practical improvement and theoretical refinement; cycles of design, enactment, analysis, and revision; and attempts to link processes of enactment to outcomes of interest" (pp. 19–20). Conjecture mapping could be likened to "hypotheses about how learning happens in some context and how to support it" (Sandoval, 2014, p. 20). Accordingly, the working hypothesis for the SILO project is that students and teachers will expand their knowledge and skills in STEM by having a daily focus built into each day. The challenge then is how to do this in a seamless and sustainable way. Figure 1 is the initial conjecture map for the SILO project.

There are three distinct phases for the SILO project, namely initial planning, implementation and translation:

1. 2021—Initial planning phase. The first phase involved selecting learning outcomes and names for the 28 units in consultation with the teaching staff at a regional state primary school. The idea of 28 units is that there is one unit for each term from Foundation to year 6 (i.e., 4 × 7).
2. 2022—Implementation phase. The second phase will involve working collaboratively with the primary school teaching staff in their classrooms. The participants are the teachers, not the students.
3. 2023—Translation phase. The final phase of the project involves visits to other schools to see how the SILO units could be utilised in their own context while continuing to work with pilot school to investigate how much scaffolding the teachers need compared to the previous year.

All three phases of the SILO project have been conceptualised with the understanding that teachers are extremely busy and that research must be meaningful and fit for purpose. A recent report titled *What, why, when and how: Australian educators' use of research in schools* (Walsh et al., 2022) found that "Educators want research and evidence to be 'usable'. Usable research or evidence is contextually relevant, practical and convenient" (p. 4).

The five data sources

The SILO project has five distinct data sources, namely anecdotal records, researcher's reflexive journal, focus groups, research report and the 28 STEM units. Each of the 28 units could be considered a separate source, but they are viewed collectively for the purposes of describing the project. Concurrently working on 28 units could be considered a massive undertaking, but the rationale for having all 28 is to expand the evidence base for STEM education throughout all of the primary years. Figure 2 shows how the various data sources involve combinations of teacher reflection and construction with researcher reflection and construction.

The data collection methods correlate with the three research questions as follows:

1. "How can project-based learning promote, sustain and embody an integrated STEM curriculum?" The careful documentation of the 28 STEM units seeks to embody the answer to this question by trialling and refining each

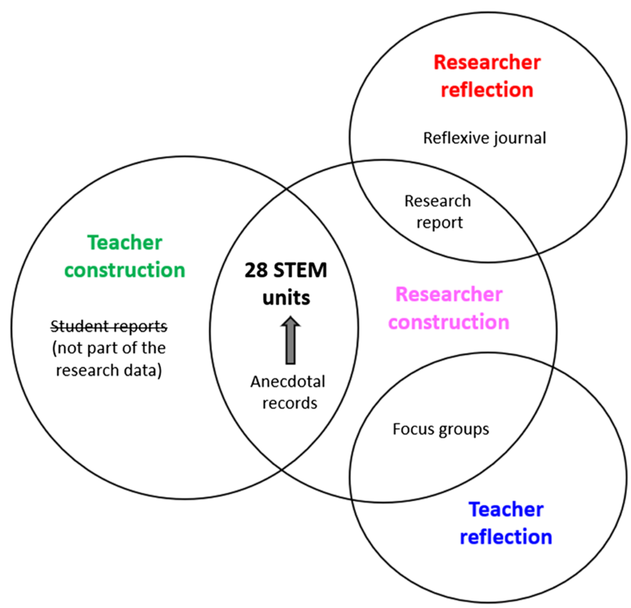

Fig. 2 Venn diagram of the data sources

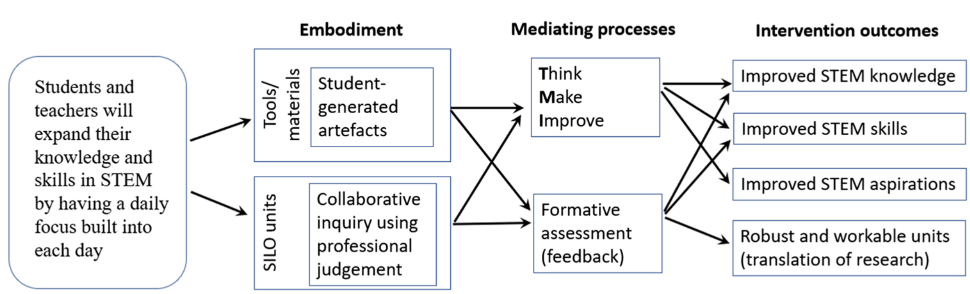

Fig. 1 Initial conjecture map for a daily STEM focus in primary schools

STEM unit in a classroom setting. Feedback from teachers came from anecdotal records and focus groups. To minimise disruption, the focus groups occur as part of the regular team planning meetings and staff meetings.

2. “How can co-design of research between teachers and researchers be effectively undertaken to improve quality and usability of project findings and recommendations?” Provisional answers to this question are recorded in the researcher’s reflexive journal. The use of this journal is to ensure that all research findings and theorising are captured and dated to provide a detailed chronology of the project.
3. “How does evaluation and translation of research best occur in classrooms and schools?” DBR allows for the articulation of an initial answer to this final question in the form a hypothesis. The working hypothesis is that translation of research can be built into this research project using the dynamics of collaboration where teachers and researchers work together as co-designers. This will ensure that research findings are usable because they have been developed using a grassroots approach within the hustle and bustle of the classroom.

According to Sandoval (2014), “the success of any design endeavour requires making some commitment to articulating what desired outcomes will look like and how they might be observed or measured” (pp. 24–25). Measuring and assessing the SILO project involve the professional judgment of the teachers involved in the project. To reduce extraneous demands on the time of the participating teachers, their own anecdotal records about the STEM units are not required to be given to the researcher or to take any specific form. The researcher’s anecdotal records are recorded in a notebook, and ideas relating to the refinement of each unit are implemented directly into the individual web page for that unit. The desired intervention outcomes of improved STEM knowledge, skills and aspirations are documented using qualitative methods pertaining to case studies using rich descriptions of children’s learning recounted by their teachers. Yin (2014) recommends using an explanatory case study for these types of studies as they involve “operational links needing to be traced over time, rather than mere frequency or incidence” (p. 10).

Throughout the project, data is uploaded to a purpose-built website (https://www.silo.edu.au). This is a distinctive element of this research as it harnesses two of the affordances of digital scholarship, namely quality and visibility (Jacobs, 2021). There is an assumption that much of what is ‘published’ on the Internet has reached a final state of refinement, but the provisional nature of the SILO website is based on a different assumption, namely that ongoing and instant access to the latest version of each of the 28 units is the most efficient and manageable way to maintain and build momentum throughout the project. To make this clear, a disclaimer has been added to each of the lesson plan pages stating that, “DRAFT—These lessons plans are embryonic in development and will be updated throughout 2022”.

Data analysis and results

The data analysis for the SILO project revolves around the refinement and implementation of the 28 units as the embodiment of learning. In DBR, the research design is in a state of continual refinement through collaboration with the classroom teachers. This is a unique affordance of DBR as the research design is treated with equal importance to the empirical data (Sandoval & Bell, 2004).

After 12 months of research in this longitudinal study, some early findings can be reported about the initial planning phase of the project in relation to naming the 28 units and choosing the specific learning outcome which formed the basis for each unit. During discussions in a focus group, it became clear that the teachers did not have time to work with a ‘blank canvas’ and that they wanted the researcher to do this initial planning work. In addition to the stated lack of time, teachers believed that this would also ensure that the scope and sequence of the project was logical and balanced over the primary years as most teachers were only focussed on their particular year level.

The fact that teachers wanted to focus on the classroom activities more than the overall planning of the scope and sequence also had unforeseen benefits relating to the navigation and design of the SILO website (https://www.silo.edu.au). The formulation of naming conventions for the individual webpages and the overall design became consistent precisely because this task was not a collaborative effort. Teachers were then able to interact with the website as a cohesive whole and their initial feedback was that the structure and functionality of the site is appropriate for their needs moving forward. The teachers also reported that they appreciated not having to learn a new system or have new usernames and passwords as all updates are made by simply sharing their ideas with the researcher in any way which was convenient, namely verbally, on paper, or via email.

Teachers have also reported that they would like to have workable STEM ideas and activities that they can implement in their classrooms now rather than waiting until all of the planning has been completed. This feedback is characteristic of DBR as “researchers would systemically adjust various aspects of the designed context so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts” (Barab & Squire, 2004, p. 3). This phenomenon of iteration leading to theorisation came into focus when selecting the 28 learning outcomes as each iteration was counted to see how the component disciplines within STEM were represented. This became a theoretical issue as to whether the STEM areas should be equally represented. Through further discussion during focus groups, there was a consensus that only genuine connections between the component disciplines should be emphasised. This point was vividly made at one of these meetings when a comment was made that “we shouldn’t be worried about hurting STEM’s feelings”.

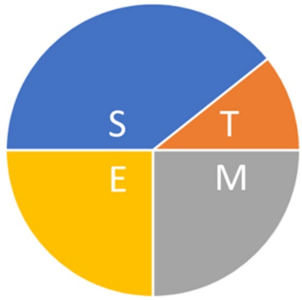

Fig. 3 Distribution of the 28 units

Figure 3 is a quantitative representation of the distribution for the curriculum mapping showing that there are more learning outcomes from the science learning area (11) and fewer from ICT (3). Engineering and mathematics have 7 each.

Each of the 28 units has a focus learning outcome, but ICT is a recurring theme as the ICT outcomes are used repeatedly. By contrast, some of the science outcomes are more specific and only relevant in certain units which accounts for their greater frequency. It is commonly understood that STEM is an integration of its component parts, but Timms et al. (2018) remind us that it can be "in any dyad, triad or ideally all four disciplines" (p. 2). Furthermore, of the four subjects, "engineering seems to offer the best scope to create problem-based curriculum units that allow integration of the subject areas" (p. 23).

Figure 4 shows an example of the curriculum mapping for a year 2 unit titled *Construction zone*. Each of these curriculum maps includes a complete listing of the learning outcomes for every learning area of the Australian Curriculum. The only exceptions are specialist areas such as visual arts which are generally taught and assessed by a different teacher. The curriculum codes are either in bold (highly applicable) or strikethrough (not covered). The focus outcome is listed in red and written verbatim under the heading.

Teachers work with the full curriculum documents which contain the exact wording for each learning outcome. However, Fig. 4 would become unwieldly if all of the wording was included so this information is provided as hover text in a digital web-based format. A summary of the 28 units will now be presented to outline the current scope and sequence of the SILO project.

Foundation

During the first year of primary school, it is important that children develop their natural sense of curiosity by exploring the world around them. Accordingly, the entry point is to "Participate in guided investigations and make observations using the senses" (ACSIS011) leading into "Science involves observing, asking questions about, and describing changes in, objects and events" (ACSHE013). The second

SILO 2.3

Year 2, Term 3: Construction zone

"Use materials, components, tools, equipment and techniques to safely make designed solutions." (ACTDEP007)

English		Mathematics		Science	Design and Technologies	Digital Technologies
Language	Literature	Number and	Measurement	Science		
ACELA1460	~~ACELT1587~~	Algebra	and Geometry	Understanding	Knowledge and	Knowledge and
ACELA1461	~~ACELT1589~~	~~ACMNA026~~	~~ACMMG037~~	~~ACSSU030~~	Understanding	Understanding
ACELA1462	~~ACELT1590~~	~~ACMNA027~~	~~ACMMG039~~	ACSSU031	ACTDEK001	ACTDIK001
ACELA1463	~~ACELT1591~~	~~ACMNA028~~	~~ACMMG040~~	ACSSU032	ACTDEK002	ACTDIK002
ACELA1464	~~ACELT1592~~	~~ACMNA029~~	~~ACMMG041~~	ACSSU033	~~ACTDEK003~~	Processes and
ACELA1465	~~ACELT1593~~	ACMNA030	ACMMG038	Science as	ACTDEK004	Production Skills
ACELA1466	~~ACELT1833~~	~~ACMNA031~~	ACMMG042	a Human	Processes and	ACTDIP003
~~ACELA1467~~	Literacy	~~ACMNA032~~	ACMMG043	Endeavour	Production Skills	ACTDIP004
~~ACELA1468~~	ACELY1665	ACMNA033	~~ACMMG044~~	ACSHE034	ACTDEP005	ACTDIP005
~~ACELA1469~~	ACELY1666	~~ACMNA034~~	ACMMG045	ACSHE035	ACTDEP006	ACTDIP006
ACELA1470	ACELY1789	~~ACMNA035~~	ACMMG046	Science	ACTDEP007	
~~ACELA1474~~	ACELY1667	~~ACMNA036~~	Statistics and	Inquiry Skills	ACTDEP008	
~~ACELA1824~~	~~ACELY1668~~		Probability	ACSIS037	ACTDEP009	
~~ACELA1825~~	~~ACELY1669~~		ACMSP047	ACSIS038		
~~ACELA1471~~	ACELY1670		ACMSP048	ACSIS039		
~~ACELA1823~~	ACELY1671		ACMSP049	ACSIS040		
ACELA1472	ACELY1672		ACMSP050	ACSIS041		
	ACELY1673			ACSIS042		
	ACELY1674					

Fig. 4 Example of the curriculum mapping for a year 2 unit

half of the year has more of a science focus using a traditional topic, namely "Living things have basic needs, including food and water" (ACSSU002). The final unit paves the way for the design process by looking at the properties of materials "Objects are made of materials that have observable properties" (ACSSU003). The names of the Foundation units are (F.1) *Investigations*, (F.2) *Changes*, (F.3) *Living things* and (F.4) *Materials*.

Year 1

Year 1 starts with a focus on mathematics and making graphs as an introduction to data collection "Represent data with objects and drawings where one object or drawing represent one data value. Describe the displays" (ACMSP263). Additional mathematical understanding is explored as the children "Recognise and classify familiar two-dimensional shapes and three-dimensional objects using obvious features" (ACMMG022), to develop their spatial awareness and geometric reasoning. Some physics content in then introduced through everyday phenomena where "Light and sound are produced by a range of sources and can be sensed" (ACSSU020). Year 1 concludes with a design focus as children "Generate, develop and record design ideas through describing, drawing and modelling" (ACTDEP006). The names of the year 1 units are (1.1) *Graphs*, (1.2) *Shapes and objects*, (1.3) *Light and sound* and (1.4) *Design*.

Year 2

Year 2 starts with an introduction to algebra through the recognition of number patterns as students "Describe patterns with numbers and identify missing elements" (ACMNA035). The focus for the second term incorporates ethical understanding which the Australian curriculum describes as a 'general capability' where "People use science in their daily lives, including when caring for their environment and living things" (ACSHE035). The next focus involves materials and tools for constructing design projects where students "Use materials, components, tools, equipment and techniques to safely make designed solutions" (ACTDEP007). Keywords such as data and variables are embedded in the final unit which asks children to "Identify a question of interest based on one categorical variable. Gather data relevant to the question" (ACMSP048). The names of the year 2 units are (2.1) *Patterns and algebra*, (2.2) *Caring for life*, (2.3) *Construction zone* and (2.4) *Data and variables*.

Year 3

Year 3 commences with a core science topic, namely "Earth's rotation on its axis causes regular changes, including night and day" (ACSSU048). Related ideas such as seasons and the heliocentric model are also integrated during this term using historical stories as part of the *Science as a human endeavour* science strand. Classification constitutes the next focus as children explore how "Living things can be grouped on the basis of observable features and can be distinguished from nonliving things" (ACSSU044). Geometric knowledge is then applied to basic coding challenges where students "Define simple problems and describe and follow a sequence of steps and decisions (algorithms) needed to solve them" (ACTDIP010). The final project involves using elements of the *Science inquiry skills* science strand to formulate and test various hypotheses. "With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge" (ACSIS053). The names of the year 3 units are (3.1) *Night and day*, (3.2) Classification (3.3), *Coding* and (3.4) *Questioning and predicting*.

Year 4

The first outcome for year 4 is very important but also quite broad as this physics concept could be applied to anything from a rubber duck floating in a bathtub to a meteor colliding with Jupiter; "Forces can be exerted by one object on another through direct contact or from a distance" (ACSSU076). Students' prior knowledge about materials is then combined with their latest understanding about forces to "Investigate how forces and the properties of materials affect the behaviour of a product or system" (ACTDEK011) in the context of simple machines. Ideation is one of the ultimate goals of STEM education, so this concept is introduced in year 4 with a focus on communication as students "Plan, create and communicate ideas and information independently and with others, applying agreed ethical and social protocols" (ACTDIP013). Data analysis rounds out year 4 building on prior knowledge about graphs and variables as children "Recognise different types of data and explore how the same data can be represented in different ways" (ACTDIK008). The names of the year 4 units are (4.1) *Simple machines*, (4.2) *Transportation*, (4.3) *Ideation* and (4.4) *Data analysis*.

Year 5

Year 5 begins with an integrated approach to farming and agriculture as children "Investigate how and why food and fibre are produced in managed environments and prepared to enable people to grow and be healthy" (ACTDEK021). The mechanical advantages and affordances of various machines enable children to apply physics knowledge in a design context to "Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions" (ACTDEP026). Elements of fair tests such as data and variables are formalised in this next unit as children "Decide variables to be changed and measured in fair tests and observe measure and record data with accuracy using digital technologies as appropriate" (ACSIS087). The previous year 4 unit on ideation is further extended into entrepreneurship and innovation as children "Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques" (ACTDEP025) including an introduction to business and finance. The names of the year 5 units are (5.1) *Food and fibre*, (5.2) *Problem solving*, (5.3) *Fair tests* and (5.4) *Innovation*.

Year 6

Electric circuits are investigated as the first topic for year 6 as children learn that "Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources" (ACSSU097). A focus on René Descartes is then used to "Introduce the Cartesian coordinate system using all four quadrants" (ACMMG143) where Cartesian geometry is presented as a synthesis of algebra and geometry. The electrical knowledge from term 1 is extended into robotics as children "Investigate how electrical energy can control movement, sound or light in a designed product or system" (ACTDEK020). The metric system might seem like an anticlimactic way to conclude the SILO project, but the logic behind the metric system combines mathematics and science as children "Convert between common metric units of length, mass and capacity" (ACMMG136). The key ideas are to understand how the Celsius scale is calibrated around the properties of water and that water is also used to link weight and volume (i.e., 1 litre of water weighs 1 kg). The names of the year 6 units are (6.1) *Electric circuits*, (6.2) *Cartesian geometry*, (6.3) *Robotics* and (6.4) *The metric system*.

Three themes have emerged thus far across the 28 STEM units, namely science inquiry skills, data and variables and design. These three themes have been identified in two or more of the units which reflects elements of the spiral curriculum proposed by Bruner (1966). These themes warrant further explanation as they might signal the essence and future direction of STEM education. They will be recounted in the order of the STEM acronym as follows:

> Science: Science inquiry skills are evident in units F.1 (Investigations), 2.4 (Data and variables) and 3.4 (Questioning and predicting). These skills represent one of the three strands of the Australian Curriculum (Science) comprising five areas, namely (1) Questioning and predicting, (2) Planning and conducting, (3) Processing and analysing data and information, (4) Evaluating and (5) Communicating.
>
> Technology: ICT was not identified as a theme and occurred the least out of the four disciplines (i.e., 3/28). This is not surprising as it indicates that ICT is a tool and context for STEM education.
>
> Engineering: The design cycle is evident in units 1.4 (Design), 2.3 (Construction zone), 4.3 (Ideation), 5.2 (Problem solving) and 5.4 (Innovation).
>
> Mathematics: 'Data and variables' was a theme evident in units 1.1 (Graphs), 2.4 (Data and variables), 4.4 (Data and analysis) and 5.3 (Fair tests). Note that units 2.4 and 4.4 also overlap with the science inquiry skills sub-strand, 'Processing and analysing data and information'.

It should also be noted that each of these themes does not fit neatly within the STEM component disciplines. For example, science inquiry skills extend beyond science to involve data and variables from mathematics. Data and variables also bring in other disciples such as the representation of data (Technology) and fair tests (Science). Perhaps the hallmark of STEM is *Design* (Engineering) as suggested by Timms et al. (2018) as "engineering seems to offer the best scope to create problem-based curriculum units that allow integration of the subject areas" (p. 23). The cross-pollination evident across the various disciplines is an exciting development as intrinsic overlaps such as these provided the rationale for the STEM acronym in the first place.

Discussion

An integral part of this research involves integrating the curriculum. Time is a limited resource in schools so the idea of integrating the curriculum has a long history of devising authentic and engaging learning experiences to best utilise this time. These ideas have been widely promoted by eminent thinkers such as John Dewey in his earliest works and most notably in his final book on education titled *Experience and education* (1938). According to Williams (2017), in Dewey's model "children will be seen learning by doing in these classrooms and they will be solving problems through hands-on approaches" (p. 93).

More recent discussions about integration often speak in terms of whether proposals are interdisciplinary, multidisciplinary or transdisciplinary (Mockler, 2018), but a bigger issue is that "integrated curriculum has been associated with school reform" (Drake & Burns, 2004, p. 28). "Bridging across the mile-wide and mile-deep chasm" (Li, 2007, p. 33) has been a related and persistent issue in education because there is a valid concern that something important might be left out. Working from the position that depth should be prioritised over breadth, participating teachers will be asked if they believed any important areas or elements were sacrificed or compromised to accommodate the project. This is a crucial issue as the sustainability of any curriculum reform resulting from the SILO project is essentially seeking proof of concept.

When the daily STEM focus is implemented in 2023, the resultant change to the timetable has the potential to signal a permanent and necessary change to curriculum reform but not as we currently know it. Curriculum is often seen as *what* we teach and pedagogy as *how*, but the proposed curriculum reform is pedagogical as the integration of existing curriculum outcomes is primarily a matter of design and implementation, as embodied in the 28 STEM units.

Sandoval and Bell (2004) noted that a central question for all DBR is, "How does the effort to design complex interventions influence research?" (Sandoval & Bell, 2004, p. 200). DBR was developed to work within the context of classrooms rather than laboratories, but this key strength is simultaneously its greatest weakness, namely causal attribution as researchers often change the intervention as it unfolds, which mirrors the dynamic and contingent nature of classroom teaching. Barab and Squire (2004) posed similar concerns asking "How do we account for the role of the researcher in the design experiments and the associated threats to validity that they bring with them?" (p. 10).

Although translation of research is one of the three research questions for the SILO project and will become the focus in 2023, Guba and Lincoln's (1999) seminal work in this area proposed that researchers provide a detailed and sufficiently thick description to the extent that others might be afforded a "vicarious experience of it" (p. 148). The purpose of the vicarious experience is to enable others to make judgements about a study, particularly about the researcher's working hypotheses, which might be transferable to another context. Lincoln and Guba (1985) describe transferability in relation to a transfer between the *sending* and *receiving* contexts and further note that "transferability inferences cannot be made by an investigator who knows *only* the sending context" (p. 297 original emphasis). Establishing the feasibility for transferability then becomes the responsibility of the researcher in the receiving context as "the burden of proof lies less with the original investigator than with the person seeking to make an application elsewhere" (Lincoln & Guba, 1985, p. 298).

Another important methodological issue is co-construction and how teachers and researchers understand their own role as co-designers within the classroom. This issue is at the heart of DBR as participants "are treated as co-participants in both the design and even the analysis" (Barab & Squire, 2004, p. 3). This will become most apparent in the SILO project during the current implementation phase where teachers and the primary researcher seek to design engaging and authentic opportunities to engage in STEM education. Much time and effort has gone into cultivating a learning environment based on mutual trust and respect to encourage the free flow of ideas in a spirit of collaboration. As yet, there have been no differences of opinion regarding implementation, but the following three protocols are proposed to manage such instances:

1. Ultimately, it is the classroom teacher who has the final say about what happens as it their classroom as they have a duty of care for everything which occurs.
2. If the researcher suggests an activity which is unfamiliar to the classroom teachers (such as robotics or coding), the researcher will run the session so that the classroom teacher can observe without having to invest any additional preparation time
3. If two or more classroom teachers within the same year level have a difference of opinion in relation to classroom activities, each teacher will remain free to pursue their chosen option. Such instances are likely to be generative as, "It is through understanding the recursive patterns of researchers' framing questions, developing goals, implementing interventions, and analysing resultant activity that knowledge is produced" (Barab & Squire, 2004, p. 10).

Conclusion

The unique contribution of the first phase of this longitudinal study is the articulation of a working hypothesis that a daily STEM focus can be achieved through careful integration of the existing curriculum. Accordingly, the SILO project is as much about change management as curriculum integration as it utilises the co-design of 28 STEM units at the grassroots level to connect theory and practice and achieve authentic research translation. There is no doubt that the stated plans will continue to change and evolve, but the inherent flexibility and strength of the DBR model is that such changes are not only anticipated but also embraced, demonstrating a shared commitment to lifelong learning at the community level.

Not all students will want to pursue a STEM career nor should they. However, the skills and knowledge associated with problem-solving and critical thinking can provide an important and lasting foundation for young people as they become increasingly capable citizens in a rapidly changing society.

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Declarations

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Conflict of interest The author declares no competing interests.

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