STEM Education: Proceed with caution

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Introduction

Proposals for science, technology, engineering and mathematics to be presented in the secondary curriculum in an integrated way have been developed in some countries for at least three decades now, but are recently becoming more common and more significant. Some proposals are now being delivered with high level political clout, for example President Obama's November 2009 announcement of a range of STEM initiatives, and the UK appointment of a National STEM Director followed by a range of similar initiatives to promote the STEM agenda. In other countries this grouping of subjects is promoted as a coalition but not necessarily as a school curriculum organiser, for example SET (Science, Engineering and Technology) in South Africa (National Science and Technology Forum).

The rationales for the agenda are various but limited, and related mainly to vocational and economic goals, rationales not uncommon in the justification of Technology Education, though more recently marginalised as Technology Education has established its place more securely as a component of general education. In many countries, traditional technology education had a strong vocational emphasis and consequently the link with workforce needs and the economy was quite explicit. Technology as a component of general education has a less direct link with economic development, but nevertheless it remains a rationale which is often invoked.

The rationales indicate the motivation for STEM proposals: shifts in workforce patterns and downward trends in economic indicators. It is not uncommon for curricular development in Technology Education to be promoted in periods of economic downturn. Using Australia as an example, there is a clear correlation between the economic depressions of the 1890's, 1930's and 1980's and significant developments in technology education (Williams, 1996). It is not implausible that the global financial crisis of 2007-2009 is a stimulant to calls for the STEM education agenda.

The agenda for this amalgamation is being driven by vocational and economic goals. Vocational goals relate to skills shortages in science and engineering areas, "studying STEM creates a pathway to a brighter future, opening up a wide range of interesting and exciting career opportunities" (Central Office of Information, 2008). STEM strategies are designed to develop a strong supply of scientists, engineers, technologists and mathematicians (Department for Education and Skills, 2006), and the UK government has serious concerns about how vacancies in these employment sectors are to be filled in the future (Barlex, 2007). And in the USA, "a growing number of jobs require STEM skills and America needs a world class STEM workforce to address the grand challenges of the 21st century, such as developing clean sources of energy that reduce our dependence on foreign oil and discovering cures for diseases" (The While House, 2009).

The economic argument for emphasis on a STEM alignment follows this vocational rationale. The US argument goes that a focus on STEM will result in "reaffirming and strengthening America's role as the world's engine of scientific discovery and technological innovation which is essential to meeting the challenges of this century" (Obama, 2009). And similarly in the UK, "as the UK seeks to position itself against global competitors at a time of rapid economic change, the priority of increasing its capacity for innovation and enterprise becomes increasingly urgent" (STEM Programme, nd), a goal which is seen can be achieved through the promotion and national coordination of STEM activities.

The political, social and technological history of each country around the world is different, and so the resulting systems of education, and specifically technology education, are also different, and are aligned with that history. An examination of the beginning movements of a technology education curriculum in India and China are clear examples of this (Natarajan & Chunawala, 2009; Ding, 2009) with each country taking quite different approaches to technology education, despite such development taking place concurrently. The STEM phenomenon is not occurring in all countries because it is not appropriate for all countries. The discussion in this paper will focus on the UK and USA, where the STEM proposals are most common. These countries are also significant because other countries tend to follow their lead: the Commonwealth countries tend to follow the UK and some European and Asian countries tend to follow the technology education developments in the USA.

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The calls for action on the STEM agenda, as it translates to an integrated school curriculum, are broad and undefined. This should ring cautionary bells for technology educators for a number of reasons, some of which are outlined below.

Unchallengeable Curriculum

The rigidity and resilience of the school curriculum structure should not be underestimated when proposing reform – the "unchallengeable high ground" referred to by Goodson (1992) in commenting on the effects (or lack of effect) of the significant curriculum reform of the 1960's. In fact a comparison between the early days of institutionalised schooling and current school academics reveals a remarkably resilient structure of recognised disciplines. Despite authoritative calls for reform from the likes of Carl Rogers (1969), A. S. Neill (1960), Carl Bereiter (1974), Ivan Illich (1971) and Paulo Freire (1971), and the research and debate that accompanied these ideas, the structure of the school curriculum remains largely unchanged. And this is not for the want of opportunity. Take the current situation in Australia for example, where a national curriculum is being developed from a history of five independent state educational systems since Federation in 1901. This ideal opportunity for innovation and rejuvenation of an educational system is being utilised to entrench a conservative and traditional system.

Despite the hundreds of thousands of well educated people who spend their lifetimes devising ways (pedagogy) and means (content) of capturing children's interest in the things that go on in school, children steadfastly and consistently are much more interested in what goes on outside school. Given the internationally common and enduring problem of student alienation, it is surprising that there are not many alternative approaches to formal education. Venville, Wallace, Rennie and Malone (2002) considered this issue and concluded that there are many factors mitigating against changes in traditional school discipline curriculum structures, including "assessment, parental pressure for traditional standards and subject-based qualifications, instructional periods, textbooks, curriculum guides and staff who are trained in their disciplines and have developed long standing attachments to them" (p. 54).

It would require a very radical curriculum approach to take out all the time in the school day that is occupied by science, technology and mathematics, and put back a sequence of learning activities that would represent an integrated approach to achieving the essential skills and knowledge of these three subjects, plus engineering. Support for a STEM approach to curriculum design must proceed with the understanding that school curriculum structures are very resistant to change.

Clarity

National programmes have been established in the UK, USA and South Africa to co-ordinate STEM activities. Both in the USA and the UK (Department for Education and Skills, 2006) initial enquiries into existing STEM projects revealed a significant amount of government support, but a completely unco-ordinated approach. So part of the major national response has been the co-ordination of existing activities. In the USA this has been compounded by a number of high profile partnerships involving leading companies, foundations, non profit organisations and science and engineering societies to form part of the 'Race to the Top' programme. Little clarity remains however on what a co-ordinated approach means in the school curriculum.

As Sanders (2009) reflected:

> I am sceptical when I hear STEM education used to imply something new and exciting in education. Upon closer inspection, these practices usually appear suspiciously like the status quo educational practices that have monopolised the educational landscape for a century. Pending evidence to the contrary, I think of STEM education as a reference to business as usual - the universal practice in American schools of disconnected science mathematics and technology education...a condition that many believe is no longer serving America as well as it should/might (p.21).

Sanders' scepticism is reinforced by an examination of the projects that have been developed for teachers and are available online to support teachers wishing to implement STEM activities into their school (for example: www.stemtransitions.org). The projects generally do not integrate science, technology, engineering and mathematics but do bits and pieces of a couple of these subjects, and detail activities which primarily achieve the goals of science or mathematics. In fact the sub-title for the STEM Transitions is "Enhancing Mathematics and Science rigour through evidenced-based curriculum projects".

Pitt (2009) summarises the ambiguities in this approach:

> STEM as an educational concept is problematic. There is little consensus as to what it is, how it can be taught in schools, whether it needs to be taught as a discrete subject or whether it should be an approach to teaching the component subjects, what progression in STEM education is, and how STEM learning can be assessed (p.41).

Even if an integrated curriculum was possible, it is probably quite unrealistic to expect such an approach to be successful in the short term in secondary schools because of the staffing implications. Primary school teachers generally already teach all subjects to one class of students, so an integrative approach is not such a radical move at this level. Individual secondary teachers, however, would not be able to develop the expertise required in all the STEM subject areas to enable an individual teacher to provide an integrated approach. Therefore a system of team teaching would be necessary, along with all the accompanying school organisation and timetable implications. Teachers would need to be trained for this type of approach.

When the subject of Engineering Studies was first introduced into the curriculum in Western Australia, the initial briefing was attended by both science and technology teachers in about equal proportion. It was logical that such a subject be team taught – the technology teachers had the material knowledge and the design and practical skills, and the science teachers had the understanding of the scientific principles. However at the conclusion of the implementation phase, it was observed that no science teachers were involved with the subject which was entirely taught by technology teachers. The difficulties of school resource allocation and timetabling seemed insurmountable to enable this level of co-operation.

One of the goals promoted by the STEM agenda is 'STEM literacy'. As a vague idea, this is laudable, but as an educational outcome it is problematic. Scientific literacy, technological literacy (and technacy (Seemann & Talbot, 1995)) and particularly numeracy are reasonably well researched and defined, but something that is an amalgam of the three has not been developed nor trialled and tested. Consequently, it is difficult to develop an academic programme (STEM) when the goals are not defined.

One implied definition is provided by Sesame Street's Early STEM Literacy Initiative (Sesame Workshop, 2009) which has a major focus on mathematics in the early years, and is formally part of a two year science initiative related to developing an understanding of the natural world. If this approach which prioritises mathematics and science represents STEM literacy, then the goals of engineering and technology are ill considered.

So at the moment there does not seem to be any clarity about what STEM education might look like in schools in terms of how the subjects could relate to each other, and the early evidence, which should make technology educators very cautious, is that Technology will become a tool to achieve the goals of Science and Mathematics.

Vocational and General Education

There is an explicit vocational approach in the STEM agenda, mainly related to science and engineering. While the UK government paints a broad approach to vocational goals and refers to increasing the flow of qualified people into the STEM workforce, its more specific concern is the large number of engineering graduates from India and Pacific rim countries and the concurrent declining numbers of engineering graduates in the UK (Barlex, 2007). Project Lead the Way (2005) represents an integrated approach to STEM education and specifies one goal as preparing students for university engineering courses. A number of Technology Education researchers also see STEM education as providing a career pathway to an engineering profession (Dearing and Daugherty, 2004; Wicklein, 2006).

In this context, the validity of such a strong vocational bias is debatable. Pitt (2009) questions this morality of "exposing all learners to STEM when only a few of them are going on to STEM based careers" (p 42). Millar et al (2006) brands this vocational goal of STEM education unacceptable social engineering on a grand scale.

STEM education is also being proposed as a component of general education, by endeavouring to improve the level of STEM literacy in the population (Department for Education and Skills, 2006) and increase STEM skills overall for everybody (Holdren, 2009). The incompatibility of such dual attempts to satisfy both general and vocational approaches in the one course has been indicated in the past (Williams, 1998): the goals of each approach are different, the assessment methods are different and the fundamental teaching methodologies are different.

The process and the knowledge related to the areas of Technology and Engineering education are also different in that Technology is more appropriately a component of general education, and Engineering studies, being narrower and relating to a specific profession, are more vocational. The implication in terms of the school curriculum is that Technology is a component of primary and lower secondary, and Engineering is part of the upper secondary schooling.

A compounding difficulty is the extremely flexible use of the terminology. From a recent conference I collected a brochure titled 'Kindergarten Children as Engineers'

(University College Lillebaelt, n.d.) and thought that this destroys my notion of Engineering as a vocational subject which should most appropriately residing in the upper secondary curriculum. However the descriptive text of this project made no mention of engineering, and referred to children's play and productivity, self discovery, experimentation, innovation, hands-on learning and the craft and cunning of Sloyd: not really identifiably Engineering.

Technology teachers must exercise caution in developing curricular alignments that are incompatible, as STEM approaches seem to be in having both general and vocational rationales for this alignment.

Alignment

The rationale for the alignment of technology with science and maths does not seem to have been seriously elaborated in the STEM agenda. This has been a traditional triumvirate, and while there are certainly well established links between these subjects, it has been recognised for many decades that "technology has just as much to do with the arts as with the sciences" (Ashby, 1958), though to a certain extent the link with the arts and other social sciences has been a neglected aspect of technology education.

The alignment of technology with engineering has a clear link, as engineering is a subset of the broader area of technology. Although why engineering has been selected as the technology to link with in schools could also be questioned – why not other non-engineering technologies such as food technology, architecture, biotechnology or communication technology? One suspects it is because engineering organisations have been active in recognising that involvement in the school curriculum may help ensure an increased supply of students into engineering university courses, and subsequently engineers (Katehi, Pearson & Feder, 2009). The danger with this alignment (technology and engineering) is that many other technologies, about which students should be aware in developing an informed technological literacy, will not be included in a school curriculum.

The curricular alignment with science and mathematics in a STEM approach would limit the opportunities for technology to be fully explored into areas of the arts, social sciences and areas of technology other than engineering.

Dominance

There is ample evidence that Technology Education would be overwhelmed in a STEM approach to the curriculum. When Science and Technology as a subject is offered in primary schools, science is prioritised and consequently technology is not delivered well (Williams, 2001); and Science and Technology, when taught as a single subject in secondary schools, tends to be quite academic rather than practical (Williams, 1996). In addition, the school and curriculum emphasis on Science, Technology and Mathematics is not equivalent across these areas. Even the earliest integrated approaches involving these subjects served the need for reform in Science and Mathematics (LaPorte and Sanders, 1995) rather than the goals of Technology.

Proposals for the STEM agenda most often overlook technology education as a significant component. Relevant documents are replete with references to improving student achievement in mathematics and science, improving the quality of mathematics and science teachers; and even technology educators promote goals such as increasing interest, improving competence and demonstrating the usefulness of mathematics and science (Gattie and Wicklein, 2007).

In reporting on a STEM based professional development workshop for teachers, Felix and Harris (2010) summarised the relationship of the subjects as:

> The use of engineering and technological design principles has been suggested as a way to increase the active engagement of students and improve students learning and transfer in science and maths (p. 30).

This is a common approach, that STEM uses engineering and technology to encourage the engagement of students and improve learning in science and maths. This implies that it is only those aspects of engineering and technology which improve learning in science and maths which will be utilised in a STEM approach.

Rose's 2007 study of the perceptions of technological literacy amongst leaders of professional organisations representing science, engineering and mathematics concluded that there is no consensus on the perception of technological literacy.

> The science informants tend to value the knowledge and abilities that enable them to conduct inquiry, solve problems, evaluate, and make wise decisions about technology within a larger social context. The engineering informants value the knowledge and abilities that enable them to apply engineering design in a human-synthesised world. The mathematics informants value technological knowledge and skill that enables them to understand and use technology to do and teach mathematics, as well as to make more informed decisions about personal and societal problems (p. 50).

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In addition, Rose found that the 'SEM' leaders "did not readily associate the "T" in STEM with a curricular programme known as technology education" (p. 50), and among those who were aware of technology curriculum, there was a lack of confidence that it had the power to develop technological literacy among students.

It is not just the "T" in STEM that technology educators are concerned may be devalued, Lewis (2009) reported on a two year study by the Committee on K-12 Engineering Education and concluded that the "E" in STEM is being ignored. "There is no systematic instruction about engineering in the public schools", and "the neglect of engineering education misses an opportunity to boost interest and achievement in all of the STEM areas, including science, technology and maths" (p. 9).

It is interesting to reflect on the Science-Technology-Society (STS) movement which really began to develop momentum in the 1980's in the UK and USA. It was well researched and supported and received considerable attention through conferences and publications. Its rationale was laudable and not dissimilar to that of STEM. However as a movement it was not significantly enduring, had no long term impact on the mainstream discipline-based curriculum organisers, and while it had some effect on science education, it had little effect on technology education. There may be lessons to be learnt in the current STEM movement from the STS initiatives.

Technology does not hold as secure a place in the curriculum as science and mathematics, and any integration of these areas would prioritise the more secure subjects, resulting in elements of importance to technology education such as the identification of design problems and the development of creativity and lateral thinking being undervalued.

Epistemology

The STEM disciplines are each based on different epistemological assumptions. Science seeks to develop an understanding of the natural world through testing the generalisation of hypotheses, and so develop in students a set of predetermined beliefs about their natural environment.

Technology seeks to develop new knowledge about made things through a designerly approach which has an element of trial and error to it. The relevance of technological knowledge to a problem or design brief is defined by the nature of the problem. The information that is needed to progress the solution of a technological problem becomes the body of relevant knowledge, which of course cannot be defined prior to the analysis of the problem. This therefore also specifies the accompanying pedagogy in that content cannot be taught in the absence of a design problem. The design problem is analysed, possible pathways to a solution are projected, then the pursuit of the solution determines the knowledge that is relevant.

The knowledge needed to solve an engineering problem is pre-defined by the context, be it chemical, marine, automotive, etc. Because the context determines relevant knowledge, it is not dependent on the nature of the design problem, and so the task for the student is different in engineering and technology. This is not to say that technology is decontextualised, but that technology contexts are less associated with a defined body of knowledge than engineering. There is less scope for the student to explore and consequently define relevant knowledge in engineering. So, while they are different, the argument for integration is that these epistemological positions could be complimentary.

There seems to be little clear discussion about the similarities, differences and the relationship between Science, Technology, Engineering and Mathematics as school subjects. STEM is a confused acronym: Engineering has a different type of relationship to Technology than does Science or Mathematics. STM would be more appropriate because engineering is actually a sub-set of the broad area of technology. The Science equivalent would be to link Science, Biology and Mathematics, for example.

Goals

An examination of the goals related to student learning that are sought from a focus on STEM education reveal a range which include improving performance in science, improving performance in mathematics (Norton, 2008), improving STEM literacy (Department for Education and Skills, 2006) and improving technological literacy (Rogers, 2005). There is reasonable evidence to assume that some of these goals may be achievable, for example mathematics achievement has been recorded to improve when it is taught in a technological context (Norton, 2008). However there is just as much evidence that integration may not enhance these goals. For example Sidawi (2009) examined the literature on studies of science teachers using technology to teach science. The logic of most of these attempts was that a technological problem, solved by using the design process would provide a meaningful context to apply and thus understand science concepts. Despite the apparent logic of the idea, Sidawi found the approaches were not successful because:

- teachers did not have a grasp of the complex relationship between science and technology and assumed that technology was simply applied science;
- the students were not able to transfer their learning of science to designing technology;
- teachers did not have a deep understanding of the design process and tried to teach it as a linear, context-free process without regard to the context of the problem. (p. 269)

The technology education professional associations in the USA and UK recognise that there is a need to be involved in the STEM agenda in order to try and maintain the integrity and place of technology and engineering education in the movement. The cautious endorsement by the Design and Technology Teachers Association in the UK contrasts with the enthusiastic embrace of the ITEEA in the US which has produced some grand but unfortunately unfounded rhetoric around the STEM movement.

The International Technology and Engineering Education Association published "The Overlooked STEM Imperatives: Technology and Engineering" (2009) which, together with lists of resources supporting STEM integration, included the following possibilities as outcomes for STEM:

- energize the learning environment, revitalising the curriculum with real-world relevance;
- ignite learners' desire to explore, investigate, and understand their world;
- learners develop confidence and self-direction as they move through both team-based and independent work;
- children become more excited and confident in math and science when using technology, innovation, design, and engineering to make school subjects personally meaningful;
- STEM education is a key pathway to technological literacy for everyone;
- encourage students to think with flexibility and confidence;
- increase relevance in the educational experience while decreasing the dropout rate.

There is no shortage of wish lists of goals some would like to see achieved by a STEM alignment. From a range of authors, it is held that a STEM approach will:

- Increase interest, improve competence and demonstrate the usefulness of mathematics and science (Gattie and Wicklein, 2007).
- Improve technological literacy (Rogers, 2005) which promotes economic advancement (Douglas, Iversen, & Kalyandurg, 2004, p. 3).
- Improve the quality of student learning experiences (Rogers, 2005).
- Prepare students for university engineering courses (Project Lead the Way, 2005).
- Elevate technology education to a higher academic and technological level (Wicklein, 2006).
- Improve science and mathematics education in order to increase the flow of STEM people into the workforce and improve STEM literacy in the population (Barlex, 2008).

A general impression is that maths, science and engineering educators are all promoting their subject agendas, but many technology educators are also promoting those agendas. Kelly (2009) reported that many leaders in technology education (Wicklein, Lewis, Dearing, Dougherty) believe that developing technological literacy in students can best be delivered by teaching engineering design. Maybe technology educators are already heeding the theme of this paper and are being cautious about STEM, but there seems to be few who are promoting the goals of technology education. The agenda for this STEM amalgamation is not being driven by a desire to progress the goals of technology education.

Conclusion

The STEM movement has developed from a non-educational rationale. Although some think it may enliven the delivery of maths and science in classrooms, the social and economic rationales are those that have initiated this movement. Spurred on by the global financial crisis, it is hoped that coordination and integration of STEM activities will better equip a workforce for dealing with the contemporary nature of business and industry, and encourage more school leavers to seek further training and employment in areas of engineering and science.

The problem for educators here is that the consequent absence of a sound educational rationale for this combination of subjects inhibits its development. There needs to be a reason for integrating these subjects which relates to quality learning outcomes for students. The conclusion reached by Venville, Wallace, Rennie and Malone in 2002 remains valid:

> We have arrived at a position where it seems that research on learning in integrated settings needs to clarify the theoretical assumptions that underlie the integrated paradigm. Unfortunately, it is not at all clear what these assumptions are or whether it is possible to reconcile assumptions about integration with those about the subject discipline (p. 61).

As an educator, it is not difficult to be attracted by the logic and research that an integrated curriculum approach would be more appropriate for secondary schooling than a discipline silo approach in that it is more reflective of the

society for which students are being prepared. Hartzler's (2000) meta analysis of integrated curriculum research indicated that students taught with an integrated curriculum performed better than students taught individual subjects. The notion of fostering dispositions (Hardy, et al, 2009; Perkins, et al, 1993, Williams, in press) or inclinations (Carr, 2001) toward learning as curriculum organisers, rather than specific subject outcomes, has credibility. However, as a technology educator, I would want to ensure the centrality of technology education in a dispositional curriculum, and therein lies the problem – so do the mathematicians, scientists and engineers.

The current state of research would seem to indicate that a STEM approach to an integrated curriculum is a flawed concept, and would have consequences for Technology Education that are undesirable. In the absence of a belief that Technology Education is a fundamental component of general education for all students, a form of STEM integration in which Technology and Engineering served to enhance the goals of Science and Mathematics may not be perceived as a bad outcome. But for those who believe in the inherent value of Technology Education, its integration with Science and Mathematics would detract from its integrity.

However, given the developing momentum of the STEM agendas, it may be unwise for technology educators to isolate themselves from this movement. In addition, it may be an opportunity to reinforce the place of Technology Education in the school core curriculum. The justification for Technology Education is a battle which resurfaces periodically in many countries when curriculum reviews are underway and the proponents of technology must once again justify its place in the core curriculum. A case in point is the current curriculum changes in South Africa and Australia.

Rather than integration, a more reasonable approach may be to develop interaction between STEM subjects by fostering cross-curricular links in a context where the integrity of each subject remains respected. Interaction, rather than integration, involves providing links between the subjects when the rationale for such is clear, and is related to judgements by teachers about enhanced learning outcomes for students, rather than remote vocational goals determined by interested social groups such as engineers or politicians.

Interaction is more likely to be locally initiated than integration. Synergies must be identified at times which relate to progression of learning in the subject areas which interact, and the teachers involved must communicate these times of opportunity to each other. For example at the time spatial calculations are being introduced in mathematics, technology education projects could be developed which reinforce the mathematical concepts (architectural drafting); or when materials technology is being applied in technology education (welding ferrous metal), this could be reinforced by studying the nature of materials in science. This type of interaction is facilitated through continual communication between the subject teachers involved, and is limited to the school.

A more incidental type of interaction occurs during the development of design projects in technology. Barlex (2007b) for example has shown the potential of interaction between design and technology and mathematics and science to enhance the designing activities of students. When students in a class are all working on different design projects, opportunities for the application of knowledge from other subject areas arise incidentally, and the promotion of such links, while beneficial, is specific to the individual.

Both this incidental design based interaction, and teacher facilitated interactions between subjects are localised, and cannot be mandated nationally or regionally. It is therefore problematic for this type of interaction to be documented as part of the 'STEM movement', though it is arguably one of the most beneficial forms of cross curricular activity in technology education.

As the Royal Society (2007) noted, in order to facilitate this form of useful interaction between the STEM subjects, a 'top down' approach must be avoided. Teachers must be willing to talk to each other and to believe that interactions between subjects will result in enhanced learning opportunities for their students. The impetus for meaningful STEM links in schools must be 'grass roots' driven, and requires partnerships between teachers which 'thrive on dialogue, risk taking and a shared vision' (Barlex, 2007, p8).

While genuine interactions between subjects are most usefully teacher initiated, the disposition of teachers to work together can be facilitated through 'top down' initiatives. The provision of professional development for teachers, which highlights the potential of interaction between subjects and sensitises them to relevant opportunities will facilitate subject interaction. The incorporation and modelling of curricular opportunities for STEM interaction in teacher training programmes will also help equip teachers with the awareness they will need. Flexibility in the school timetable to permit teachers to work together would also support grass roots initiation of STEM interactions.

However, almost as many impediments remain to interaction as to integration: rigid school timetables and curriculum structures, deficient awareness by teachers of other subject areas, inflexible classroom design, and assessment. With a focus on STEM interaction, driven by teachers, interventions can be developed which will overcome these impediments. A focus on STEM integration will not overcome the barriers, and may result in the decimation of technology as a distinct component of the school core curriculum. A STEM orientation, therefore, must be approached with caution.

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