Inter-disciplinary mathematics: Old wine in new bottles?

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Early Inter-disciplinarity

The term “Inter-disciplinary mathematics” is related to, or perhaps subsumes, terms such as polymath and scientist.

Either way, we recognize Leonardo da Vinci, and Galileo Galilei as inter-disciplinary thinkers.

Inter-disciplinarity at school

The Course of Study for Primary Schools, Arithmetic, Grade VII, teachers in rural areas were reminded that arithmetic must include “Practical investigations and exercises appropriate to the major primary industries of the locality (at least two of which must be taken” (Victorian Education Department, 1954, p. 4)

And now

The modern term ‘inter-disciplinary mathematics’, and related terms, such as STEM (Science, Technology, Engineering and Mathematics) and STEAM (Science, Technology, Engineering, Arts, and Mathematics), has become prominent in recent decades.

A notable inclusion in this area is that of technology, often taken to be a reference to digital technologies, rather than technology in its broader sense.

This broader sense is, for example, “technology is the term that includes all the technologies developed and used by people in the purposeful application of knowledge, experience, and resources to create products and processes that meet human needs” (Australian Education Council, 1992).

Voskoglou (2006) claimed that mathematics was important for the Design Sciences, which, at that time in Greece, included architecture, engineering, and even medicine and economics.

This was from the perspective that “the mission of the Design Sciences is the design and manufacture of artificial objects, having certain desirable properties” (p. 134)

According to Laboy-Rush (2011)

[T]hrough an integrated approach to STEM education focused [*sic*] on real-world, authentic problems, students learn to reflect on the problem-solving process.

Research tells us that students learn best when encouraged to construct their own knowledge of the world around them …[and it] is through integrated STEM projects that this type of learning can occur (p. 1).

Effective Practices

Diaz and King (2007) suggest five characteristics of effective inter-disciplinary STEM projects

Characteristics of Effective Practice

- Students have a variety of learning tasks to involve them in the learning process;
- Students receive explicit communications and explanations;
- Students have opportunities to model solutions, practise solving problems, and receive constructive feedback;
- Students engage in a student-centred instructional environment that focuses on their interests and needs; and
- Students receive support for their learning needs.

An example

The Victorian model Solar Vehicle Challenge is a competition in which students design, make, and race model solar vehicles: these are either wheeled vehicles or boats.

In addition, entrants need to provide a poster communicating the these processes.

The posters are part of the competition and are judged before being displayed at the challenge event.

Figure 1: Model solar boats racing.

STEM Addressed

Curriculum areas addressed are science, particularly the physical sciences, in which electrical circuits, solar production of electricity, friction, and air or water resistance are important aspects.

In technology, the use of the iterative Design, Make, and Appraise (DMA) process is critical to producing an efficient model with the equipment and materials available.

And Mathematics?

The rôle of mathematics is mainly in measuring. The model must keep within the required dimensions, and measurements must be taken during model testing and these data displayed on the poster, as well as interpreted for model improvement.

And Engineering?

Engineering, particularly electrical and mechanical engineering, clearly plays a large rôle in constructing a vehicle that moves by wheels or propellers, and powered by solar cells.

For the model solar boat challenge, in particular, hull shape and the propulsion system are major aspects of the need for engineering understanding.

Is the Solar Challenge project-based learning?

If it is, then Donnelly's (2015) question, "Should we 'teach' inter-disciplinarity at school?" (p. 3) would be answered in the affirmative.

He suggests that project-based learning would teach students the inter-discipline links necessary for inter-disciplinary approaches at University or at work.

And

Making these links explicit to students can only be of benefit … [and] be of benefit to teachers too, working collaboratively across disciplines, sharing knowledge and experiences of pedagogical approaches and joint planning (p. 3).

And in Singapore

It was announced in 2015 that 42 Secondary schools offer the Science, Technology, Engineering, and Mathematics Applied Learning Programme (STEM-ALP), and that by 2017 half of the 124 mainstream Secondary schools in Singapore would offer the programme.

And in detail

Skills and competencies to be developed include:

- Scientific inquiry and literacy;
- Reasoning and problem solving;
- Design thinking;
- Computational thinking; and
- Data analysis and the use of technology.

(Ministry of Education, 2015, p. 4)

Caveats

There is always the possibility that some integrations may not contribute successful mathematical learning for the students (Becker and Park, 2011).

An example

Doig, Groves, and Williams (1996) reported on the mathematization of a science modelling activity with Primary school children aged between 10 and 11 years.

The activity involved dropping a ‘timer ball’ to discover the height from which to drop an object for a falling time of one second.

And

Two high ability 11 year-olds “spontaneously found the differences between the distances [fallen in each quarter second] and concluded that the ball was accelerating’ (p.6).

However, with a group of 10 year-olds, the authors were unsuccessful in convincing the children that this was in fact the case.

So

This example of acceleration, would suggest that inter-disciplinarity may not be a simple matter, and that a re-thinking of curriculum content and sequence may well be needed.

In the example above, some preliminary science addressing gravity may have been helpful for the acceleration activity.

Yet another caveat

(Land, 2013, p.548) claimed that adding the Arts into STEM would re-invigorate and benefit the STEM subjects.

However, Land's claims are not supported by evidence.

Madden, Baxter, *et al.* (2013) list several innovative integrated tertiary curricula starting up at the time (2013), but the benefits of these creativity courses integrated into STEM are not yet clear.

At this stage STEAM is simply hot air.

Where will it end?

Advocates for integrating religion into STEM (making STREAM) and History (making SHTREAM) have so far stopped at including Geography as the acronym is unpronounceable.

And finally a warning

In the mid-1990s Mercedes-Benz was keen to develop a car that would be “aerodynamic, safe, efficient, and maneuverable [*sic*]” (Buehler, 2015, p. 1) These criteria led designers and engineers to look to Nature for a possible solution.

This, they thought, was to be found in the Boxfish (Ostraciidae Tetrodontiformes), which had remarkable capabilities.

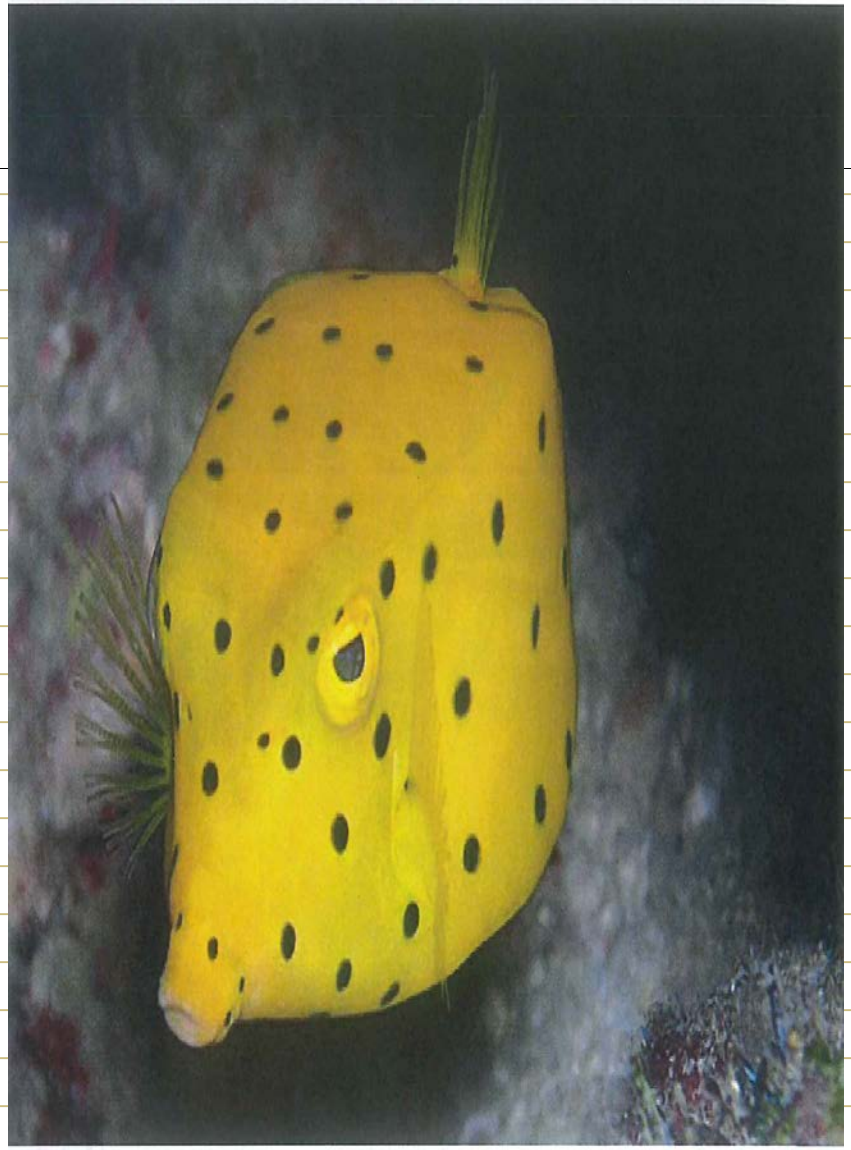

Figure 2:The Yellow Boxfish (Buehler, 2015, p. 1)

The Box Fish

For, although box-like as its name suggests, the Boxfish was thought to have excellent hydrodynamic characteristics (low drag), a spacious body, and good stability.

Further, the “carapace supposedly had unique, inherent, self-correcting stabilization properties” (Buehler, 2015, p. 1).

The Mercedes-Benz designers and engineers set out to create the Bionic concept car.

The Box Fish

But, researchers at the University of Antwerp, University of Groningen, and the University of California at Los Angeles, reported that the Box Fish shape did not have lower drag, nor did its shape promote stability, but rather, the Box Fish used its inherent instability for fast manoeuvering (Van Wassenbergh, van Manen, Marcroft, Alfaro, & Stamhuis, 2015).

The Lesson

The lesson here is that a little knowledge is a dangerous thing, and one needs to engage with those with real expertise in the particular field.

An inter-disciplinary team?

Discussion

History shows, that while claims that mathematics supports human endeavours in science, engineering, and technology are beyond dispute, the implications for educational practice are not so clear.

The curriculum of half a century ago mathematics was seen as the necessary tool for other aspects of students' lives.

Discussion (2)

The question for curriculum developers, teachers, and students is how to install inter-disciplinary mathematics into the fabric of the modern school.

Extra-curricular ideas, such as the Victorian Model Solar Vehicle Challenge may point the way for those teachers dedicated enough to make their time and expertise available, but is it sufficient that only a small proportion of students are engaged?

Other ideas

UC Berkeley's Lawrence Hall of Science's *Science Education for Public Understanding Program* (SEPUP) (2015) materials.

Other ideas

Ontario Ministry of Education introduced an Integrated Curriculum in 2006.

In such integrated curriculum approaches, Drake and Reid (2010) claim, “students … demonstrate academic performance equal to, or better than, students in discipline-based programs. In addition, students are more engaged in school, and less prone to attendance and behaviour problems” (p. 1).

And

Further, “[t]eachers, impressed by the level of classroom discussion, concluded, “integrated curriculum lends itself to higher order thinking skills” (Drake and Reid, 2010, p. 3).

However, whether these observations carry through to greater understanding and skills in the integrated subjects is yet unproved.

At University

But, are teachers ready to undertake inter-disciplinary mathematics? Or science?

The answer to this question most likely lies within the universities who educate teachers of both mathematics and the other STEM disciplines.

At University

An example, of one university approach, is that of the Aggie-Center at the Texas A&M University, where Summer Camps for teachers interested in inter-disciplinary STEM teaching are held each year (Aggie-STEM, 2015).

These are well supported and the number of applicants out-runs the number of available places each year.

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