Theme(s): Numeracy

Building mathematics skills in a vocational context

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[ORIGINAL TITLE Building academic skills in context: testing the value of enhanced maths learning in CTE.]

Could explicit teaching of mathematics within vocational subjects improve students' skills?

Various occupations require the practical application of mathematics and most employers want workers with good maths skills. Yet many students who take vocational subjects struggle with maths and problem-solving skills. Vocational subjects potentially offer rich opportunities for students to use maths to solve work-place problems. Teachers of vocational subjects sometimes give anecdotal evidence of students who finally begin to understand abstract mathematical concepts when they see them applied to real situations. This American study investigated whether teaching mathematics during vocational lessons could improve students' performance in maths and found quantifiable evidence to suggest that it could.

In the study, teachers of Career and Technical Education (CTE) subjects paired up with maths specialists to design new lessons that exploited opportunities to explore maths within a real-life context. They taught the lessons to students aged 16-18 over the course of one term. The study compared the performance of these students with others whose CTE teachers continued to teach in the same way as before. It found many modest and some statistically significant improvements in students' scores on standardised mathematics tests. Moreover, the time students spent working on improving their maths during the vocational lessons did not detract from their knowledge and skills in the vocational subject itself.

Keywords:
Numeracy, Mathematics, Problem-solving, Learning processes, Teaching and learning, Vocational guidance

Contents

How much did the students' maths improve?

The study tested around 4000 students both before the project began and after it ended. They each took one of three different maths tests and a test of knowledge and skills relevant to their own vocational subject. About half the students were taught by 114 CTE teachers randomly selected to design and teach between five and ten new maths in CTE lessons over the course of a single term. The rest of the students continued to be taught by 122 CTE teachers in their usual way.

The study tested each of the six subject areas using three different maths tests, so creating eighteen different pairs of comparisons between the students. It found that:

- in fourteen of the eighteen test comparisons, experimental groups of students scored more than their peers in the control groups;
- these higher scores were statistically significant in three instances: for two vocational subjects, this was in the maths test usually used to place college students and, for a third vocational subject, the significantly better performance was found on a test of applied maths; and
- students in the experimental group did just as well as control students on a test of vocational subject-specific skills and content knowledge.

The researchers concluded that the additional time spent on maths activities during CTE lessons did not impair students' acquisition of occupational skills and knowledge, but that it could improve their performance in mathematics. They noted that, although students in the experimental group generally improved more than their peers in the control groups, few improvements were big enough to be statistically significant. They considered **possible reasons** for this.

Students' attitudes towards maths and their motivation and confidence also improved. They became more proactive in approaching maths.

"The kids would go tell the maths teacher what I did and then they'd work out a problem in maths class … [The maths teachers would] come and ask, 'What in the world are you doing? Our kids come and ask about problems I didn't think they would be interested in!'" (CTE teacher)

"The one thing I am probably most proud of …[is] that I have more of my kids volunteering to go for remedial maths than ever before." (CTE teacher)

How did the teachers prepare for and implement the project?

The Career and Technical Education (CTE) teachers covered a variety of vocational subjects:

- business and marketing;
- information technology;
- health occupations;
- automotive technology;
- agricultural mechanics; and
- horticulture.

The 114 teachers chosen to implement the pilot project each found a maths teacher who was willing to work with them. Together, they attended a professional development workshop for their specific curriculum area. During the workshop, the teams of maths and CTE teachers identified the mathematical concepts embedded in their particular CTE curriculum. Together, they developed between five and ten lessons that would help to teach these concepts explicitly.

Each lesson had to include **specific elements**. As well as planning the lessons together during the course, the pairs of teachers met before each lesson to review the lesson plan, discuss questions that might come up and to cover any queries or concerns that the CTE teacher might have. After each lesson had been taught, the pair met again and discussed how it went, using a series of **debriefing questions** provided by the researchers. The maths teacher wrote up and submitted a report to the researchers, based on this discussion.

The maths teachers supported their colleagues before and after the lessons, but the CTE teachers had to teach the maths-enhanced lessons alone. The learning was two-way. Maths teachers described the experience as "eye-opening" and were particularly enthusiastic about learning new applications. During the project, mutual respect between the colleagues grew.

"My partner is a veteran… he's forgotten more than I'll ever know." (Maths teacher)

"We try in mathematics to get real-world applications, but [CTE] is doing it every day – they're just right in there." (Maths teacher)

What was the typical pattern of a CTE lesson designed to support students' maths?

The pairs of teachers jointly planned vocational lessons that provided explicit instruction in specific maths concepts relevant to the vocational subject. Each of these lessons was supposed to include the following elements:

- *pointing out the mathematics found in the vocational context* – teachers had to tell students when they reached the part of the lesson in which maths was embedded;
- *assessing the students' maths understanding* – the teachers asked open questions about the maths, such as, "What can you tell me about this?";
- *working through the pulled out example* – teachers worked through the steps needed to complete the example, or asked students to take the lead if their level of understanding was sufficient;
- *enhancing the maths in the lesson* – teachers identified and shared the underlying maths principles and concepts, purposely using mathematical vocabulary and asking students to do so;
- *reinforcing the maths enhancement* – teachers worked through similar examples from a work-related context and also more abstract maths examples that might be seen in a test or maths lesson; students also worked through such problems individually or in small groups;
- *checking the students' understanding* – teachers asked questions such as, "Can you explain the maths concepts we used today?" or "How would you explain these maths steps to someone else?"; and
- *expanding the enhancement* – teachers asked students to create their own examples, for both vocational and traditional mathematical contexts.

Researchers advised teachers to continue to use both sets of vocabulary (from the CTE and formal maths context) alongside one another throughout the lesson, e.g. using both 'slope' and 'pitch'. They also suggested that during the final stage of the lesson, as well as asking students to create examples of their own, teachers could provide further examples that addressed the same maths principle but which contained an error in logic, and ask the students to spot and correct this.

The study found that, although most lessons consistently used the first six elements, about one third of observations did not see evidence of teachers using the seventh element. This was unfortunate, as the final element was important, because it gave students opportunities to extend their learning into more traditional maths problems.

How did the pairs of teachers evaluate the new lessons?

After the CTE teachers taught each lesson, they discussed how it went with their maths colleague. The researchers supported this discussion by providing a schedule of useful questions, which is set out below.

Post-teaching debriefing questions

1. In general, how did it go?
2. How did your students respond? In your opinion, did students understand the maths concepts?
3. What elements of the enhancement were particularly effective?
4. What would you like to build on or strengthen?
5. What elements of the lesson were challenging or difficult to teach?
6. Were there some elements of the lesson you did not have an opportunity to teach?
7. If so, why were you unable to teach some elements of the lesson? (If the answer is 'lack of time', please identify what caused the time crunch.)
8. What would you like to do differently next time?
9. What kind of support do you need to prepare for the next enhancement?

Teacher comments

CTE teachers were very positive about the programme, although they often found it challenging, especially at the beginning.

> "The first couple of lessons, I've got to tell you…[I was a] fish out of water!"

Later, the same teacher claimed to be "having a blast!"

Teachers approved of the reinforcement of maths skills through real-life situations.

> "Maths that is given in authentic and contextual situations is more meaningful for the learner and is more powerful than rote practice." (CTE teacher)
>
> "I like these ideas. Now I can explain why these concepts are important. I knew how to do them, but I never understood how you guys use those in real life."(Maths teacher)

What did the researchers believe might improve the success of a future programme?

Although fourteen of the eighteen experimental groups of students tested scored more than their peers in the control groups, the differences only reached statistical significance in three instances. The researchers suggested several reasons for this.

Firstly, they suggested that that in some instances, the maths test used might not have been particularly sensitive to the focus of the maths instruction in the CTE class. Curriculum mapping identified varying types and amounts of maths across the six different CTE subjects and each of the three different maths tests assessed a different range of concepts. The fit of the test to the maths encountered might not have been very close.

Secondly, teachers in the experimental group followed the teaching model to different degrees. In some instances, the CTE teachers did not teach all of the maths enhancements, or did not teach them as intended. For example, many teachers struggled to implement the seventh element of the teaching model. Teachers also commented that it was more difficult to teach lessons they had not personally designed. They asked for additional support and researchers planned to include more extensive professional development and more time for developing lessons in the forthcoming full year study.

Thirdly, although teachers in the control group were supposed to continue to teach as before, some changed their usual approach to teaching during the experimental term. In some settings, students and teachers in the control group undertook school-wide maths improvement projects that may have improved control students' maths scores.

Finally, the researchers suggested that the single term duration of the project was relatively short and may have limited the gains made. They hoped to find more significant improvements during the full, year-long project.

What were the aims of the study and how was it designed?

The researchers noted that many American high school students, especially those enrolled in vocational courses, did not have the maths skills needed for those jobs or for college entrance requirements. This pilot study aimed to find out:

- whether teaching mathematical skills within a real-life context helped to develop maths skills which could be transferred to a specifically mathematical context; and
- whether time spent focusing on the maths content of vocational courses depressed the students' knowledge and/or skills of other aspects of the vocational subject.

The study involved nearly 4000 students aged 16 to18, enrolled on six different vocational courses, and 236 teachers, of whom 114 implemented the experiment and 122 acted as a control group. The teachers all volunteered to take part and were randomly assigned to the experimental and control groups. The 114 experimental teachers paired up with a maths colleague who helped them throughout the project. These pairs worked together at a professional development workshop to identify the maths concepts used within their own vocational subject and to develop between five and ten lessons that would emphasise these.

The researchers tested all the students before and after the trial term with a standardised maths test and a test on vocational knowledge and skills. They split each cohort of students into three groups and used a different maths tests with each of them. Each of the maths tests examined different aspects of maths. They were:

- ACCUPLACER – a widely used college placement examination;
- TerraNova – a traditional maths exam used by many states as a basic skills examination; and
- WorkKeys – an applied maths examination originally developed for employers to identify suitable candidates for employment or promotion.

The researchers also collected additional data from surveys, interviews, focus groups, class observations and teaching artefacts. The maths and CTE teacher partners met each other before and after each special lesson. The after-lesson meeting followed a structured pattern of debriefing and the maths teachers submitted a written debriefing report to the researchers.

What are the implications of the study?

In completing this digest the authors began to ask the following questions about implications for practitioners:

- The study found that the maths vocabulary used within CTE lessons typically differed from that traditionally used within maths lessons and that teachers needed to use both sets of language to help students see the links between the two situations. Are there other contexts in which paying explicit attention to terminology could help your students bridge the gap between theoretical and practical understanding?

- The process of mapping the curriculum and sharing teaching strategies with other teachers helped the professional development of the teachers in the study. Could a similar process benefit your own professional development?

- Teachers in the study did not always ask students to create their own examples or to spot deliberate errors in similar examples, during the final element of the lesson, although the researchers believed that this was an important step that supported the transfer of understanding between different contexts. Is this something your own students might find helpful? Could you work with colleagues to create a resource bank of suitable activities for this final phase of the lesson?

In completing this digest the authors began to ask the following questions about implications for school leaders:

- Teachers in the study found it particularly difficult to teach lessons they had not prepared themselves. What implications might this have for occasions, such as covering absence, when teachers in your school may have to teach lessons they have not personally prepared? How might the difficulties be best overcome?

- The study found that the partnerships between the teachers of vocational subjects and of maths benefited both parties and led to mutual respect and professional learning. Could pairs or small teams of teachers from different subject disciplines in your school benefit from working together to develop enhanced schemes of work?

Where can I find out more?

The full report on this pilot study is:
Stone, J. R., Alfeld, C. Pearson, D., Lewis, M. V., & Jensen, S. (2005). *Building academic skills in context: Testing the value of enhanced math learning in CTE* (Pilot study). St. Paul, MN: National Research Center for Career and Technical Education. It can be found here:
http://www.nccte.org/publications/infosynthesis/r%26dreport/MathLearningPilotStudy.pdf

Other TRIPS digests on the theme of numeracy and mathematics can be found at: http://www.standards.dfes.gov.uk/research/themes/numeracy/

The General Teaching Council offers detailed summaries of research into subjects including mathematics at: http://www.gtce.org.uk/research/romtopics/aboutrom

The National Centre for Excellence in the Teaching of Mathematics offers a useful portal for teachers of maths at all levels: http://www.ncetm.org.uk/

The Association of Teachers of Mathematics also offers a range of resources and professional support: http://www.atm.org.uk/