USING MATLAB IN SECONDARY SCHOOL MATHEMATICS INVESTIGATIONS

IAN ALLAN THOMSON

Ormiston College

i.thomson@ormiston.qld.edu.au

Abstract: Two mathematics investigations for secondary school students are presented in this paper. The investigations are intended to nurture complex reasoning processes and ways of working that are appropriate for students in approximately Years 10-12. The design of each investigation is analysed in relation to the Dimensions of Learning pedagogical framework, as well as the SAMR and TPACK models for technology integration. The tasks involve the use of MATLAB, which is software commonly used in industry and tertiary institutions. The analysis illustrates, however, that this technology is very suitable for use in secondary school mathematics investigations.

Introduction

Two investigative tasks that were written for secondary school mathematics students are referred to in this paper (see Appendices A and B). The first task is an investigation into codebreaking, and the second task is a mathematical modelling task involving shooting in basketball. Both tasks were written in alignment with the Dimensions of Learning pedagogical framework (Marzano, 1992), and designed to make use of MATLAB software (The MathWorks, 2014). The connections between the tasks and the Dimensions of Learning framework are outlined and the suitability of MATLAB software for use in secondary school mathematics is examined with reference to the SAMR (Puentedura, 2006) and TPACK (Niess, 2009) models for technology integration.

MATLAB (short for matrix laboratory) is a technical computing language which is widely used by engineers, scientists, and mathematicians in industry and education. It has capabilities in numeric computation, data analysis and visualisation, and programming. MATLAB is applied in a wide variety of fields, including satellite guidance, town planning, thought-controlled prosthetics, computational biology, robotics, and image recognition. MATLAB is also very powerful in statistical analysis, and was recently described by Jonathan Rosenberg, former Senior Vice President of Google, as the one app that people looking for a job at Google should have on their resume (Edwards, 2014). It is used in the majority of STEM-related courses in Australian universities. The use of MATLAB in secondary schools forges a useful link between school and tertiary study.

Method

Analysing the design of the investigations with reference to the Dimensions of Learning framework

Both tasks are examined through the lens of the Dimensions of Learning framework. As illustrated in Figure 1 below, knowledge is central to the Dimensions of Learning framework.

Dimension One:
Attitudes and
perceptions

Dimension Two:
Acquiring and
integrating knowledge

Dimension Three:
Extending and
refining knowledge

Dimension Four:
Using knowledge
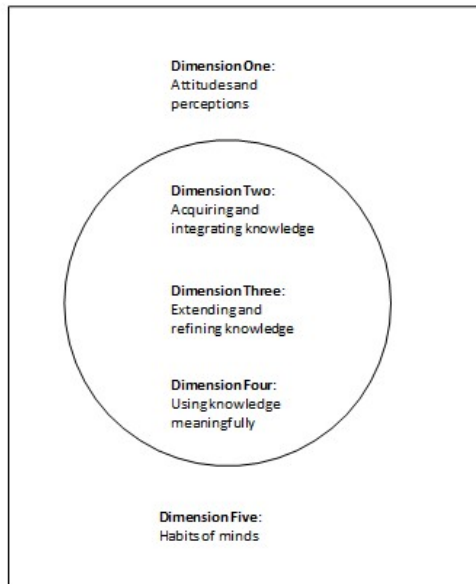meaningfully

Dimension Five:
Habits of minds

Figure 1. The Dimensions of Learning Framework.

The knowledge is described in two forms, namely declarative ('know what') knowledge and procedural ('know how') knowledge. The importance of extending and refining knowledge, and using knowledge meaningfully are emphasised in the framework. The framework extends beyond the acquisition of knowledge, however. It also addresses affective aspects of learning, including the attitudes and perceptions of learners and their ways of working. The Dimensions of Learning form a suitable frame of reference, therefore, for an analysis of investigations that are intended for adolescent learners.

Assessing the use of MATLAB with reference to the SAMR and TPACK models of technology integration

The benefit of using MATLAB in the investigations is considered with reference to the SAMR and TPACK models of technology integration. The SAMR model is a framework which helps educators evaluate technology in the classroom (Puentedura, 2006). It has four levels which can be used to assess technology integration. The first level is 'substitution', and in this level the new technology replaces a form of technology that was used previously. The second level is 'augmentation'. In this level the new technology is still essentially replacing the old method, but there are some added functionalities that enhance the learning process. The third level is 'modification'. At this level the educational process is transformed, and the technology facilitates the redesign of the

task. Finally, the fourth level is 'redefinition'. In this level, new tasks can be designed that would not be possible without the new technology.

The TPACK model for technology integration provides a framework to describe an intricate blend of teacher knowledge. It spawned from a conceptual framework outlined by Mishra & Koehler (2006). The TPACK model describes a 'total package' of teacher knowledge which encompasses technological, pedagogical and content knowledge, and, importantly, the connections between these forms of knowledge. In their study of teachers in technology-rich environments, Goos and Bennison (2007) identified the need for such a framework. This need arises from the fact that the teacher has to cope with increased levels of complexity when new forms of technology are introduced (Hoyles & Lagrange, 2010).

Analysis

Connections between the codebreaking investigation and the Dimensions of Learning framework

One of the main objectives associated with Dimension One of the Dimensions of Learning framework is to help students develop positive attitudes and perceptions to classroom tasks. There are several methods that can be used to make tasks engaging for students. These methods include creating tasks that are relevant to life outside of the classroom; ensuring that tasks provide an intellectual challenge; and stimulating interest in the task through the use of anecdotes related to the content of the task (Marzano, 1992).

The codebreaking investigation is designed to adopt these methods. In the introduction to the investigation the relevance of codes throughout history and in many areas of real life is highlighted. Closely following the introduction, an intellectual challenge is presented to the students and they are asked if they can crack the code shown below

sspaoitini oietundnom mtonleogoa eipodotsng

tsloifhtei itenmtehcn mhteahtaae eehwgahtn

This codebreaking challenge is intended to initially arouse curiosity before it is solved using mathematical techniques later in the investigation. To raise interest levels further, a story is introduced in the form of a video clip from the movie "The Imitation Game" which is about codebreaking in World War II, and which contains a clue to cracking the code.

Dimension Five of the Dimensions of Learning framework outlines the productive mental habits of mind that help students become successful learners. Persistence is identified to be one of these habits of mind. Persistence is a quality that is associated with creative thinking. Codebreakers need to use their imagination and persevere. A link can therefore be drawn between this habit of mind and the codebreaking investigation.

The codebreaking investigation includes three main tasks. The first is to decipher a code which contains a quotation from Julius Caesar. The second task is to use the technique of frequency analysis to decipher a coded message. The third task is to crack a code that has been constructed using the transposition of letters.

The tasks are all associated with stories that are designed to arouse curiosity and interest. The way that Julius Caesar coded his correspondence is described by explaining his use of the so called 'Caesar Shift' in which he shifted each letter three places to the left in the alphabet. FRIENDS ROMANS COUNTRYMEN LEND ME YOUR EARS becomes COFBKAP OLJXKP ZLRKQOVJBK IBKA JB VLRO BXOP.

Frequency analysis is connected to the true story of the plot to assassinate Queen Elizabeth 1. The contents of coded letters between Mary Queen of Scots and her followers were revealed using frequency analysis and Mary was subsequently beheaded in 1587. In the third task, the students use the technique of transposition to crack the code that was set as a challenge in the introduction and which forms the last sentence spoken in the video clip from 'The Imitation Game', i.e. "Sometimes it is the people that no one would imagine of that do the things that no one can imagine."

Using SAMR and TPACK to assess the use of MATLAB in the codebreaking investigation

MATLAB is used in the codebreaking investigation in ways that can be related to the SAMR model. In the first task there is evidence of 'augmentation' when the Caesar Shift method is automated through the use of MATLAB. This is then transformed to the higher level of 'modification' when the task is redesigned to use ASCII code rather than just the letters of the alphabet. In the second task, there is evidence of 'augmentation' in that the frequency analysis can be performed faster and more efficiently using a MATLAB program than it could be done using pencil and paper. Arguably, the sheer power of MATLAB to deal with copious amount of data increases the level to 'modification' since the students are able to analyse thousands of words rapidly from a variety of sources or languages. The third task also shows evidence of 'augmentation' when it provides an automated method of transposing text to form a code. There is scope for 'modification' since the students can use this method to create their own codes on a large scale.

The codebreaking investigation can be assessed from a teacher's perspective using the TPACK model. In this investigation the technological demands on the teacher in terms of the use of MATLAB are not high. The use of MATLAB in the investigation can often be restricted to the use of single line commands including, for example, the commands 'char' and 'double'. An example of this is given in Figure 2 below which shows a screenshot of the MATLAB desktop. The Command Window is located at the foot of the screen. The Command Window is where commands are typed in and non-graphic output is displayed. The Edit Window lies above the Command Window. The Edit Window is where program scripts can be edited. The Current Directory, on the left of the screen, is where current files are located and saved. The Workspace, on the right of the screen, shows details of variables, including their minimum and maximum values.
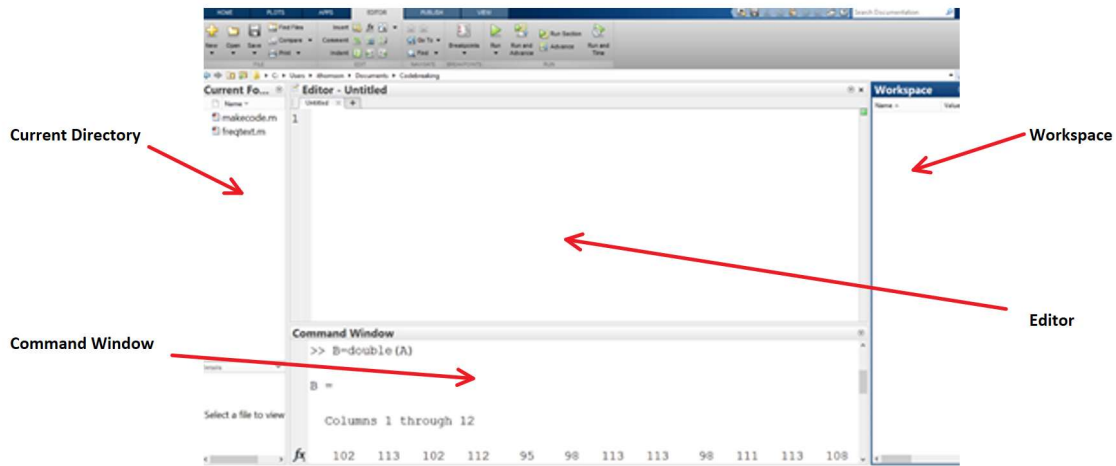
Figure 2. The MATLAB desktop.

Some program scripts are used but they are provided and the teacher only has to cope with adapting them in minor ways. The mathematical content knowledge is not overly sophisticated either and the only concept of note is the transpose of a matrix. Overall, the investigation is designed in such a way that it would not stretch too much the technological, pedagogical and content knowledge of a secondary school mathematics teacher.

Connections between the basketball shooting investigation and the Dimensions of Learning framework

The basketball shooting investigation demands a level of declarative and procedural knowledge that is appropriate for senior secondary school students. The students are expected to know what the important features of a quadratic function are and know how these features can be used to construct a graphical model of the quadratic. Concepts and facts related to trigonometry and some elementary vector calculus are also required along with a reasonable degree of procedural skill in algebraic substitution and rearranging.

The basketball shooting investigation is also designed to be engaging. Although the context is very different from the codebreaking investigation, the methods used to make the investigation engaging are similar. The investigation is associated with life outside of the classroom. It could even be introduced to the students in a basketball court. The investigation does present intellectual challenges in that it requires mathematical modelling and algebraic manipulation. The true story that the investigation is based on is perhaps the most engaging component of the design. In fact, the story is so powerful that the teacher can use it to help the students make connections with many features of the Dimensions of Learning framework. It is a tale of a young man at the end of high school who wishes to become a professional basketballer. He is not particularly tall but through a combination of dedicated practice and ingenuity he sets on a path to become the world's greatest basketball shooter.

A teacher who uses this story to introduce the investigation can help the students see the connections between the investigation and productive habits of mind that form part of Dimension Five of the Dimensions of Learning framework. 'Striving for accuracy' and 'restraining impulsivity' are habits of mind that are associated with critical thinking. 'Generating new ways of viewing a situation that are outside the boundaries of standard convention' is associated with creative thinking. These habits of mind are all depicted in the true inspiring story in which the basketballer perfects his shot and ingeniously improves it using unconventional techniques. Introducing the investigation in this way makes it relevant to students' interests and goals in a general sense. In the video clip that is incorporated in the investigation, the basketballer models self-efficacy when he writes on his shoes "I can do all things…"

Using SAMR and TPACK to assess the use of MATLAB in the basketball shooting investigation

With reference to the SAMR model, the use of MATLAB to perform curve fitting in the basketball shooting investigation can be viewed as a 'substitute' for other methods. MATLAB performs the same operation that could be carried out on a spreadsheet or a graphics calculator. There is some evidence of 'augmentation' in that the graph that is produced by MATLAB can easily be labelled and annotated. This can be done interactively using drop-down menus. Alternatively this can be performed through the creation of a script which could be adapted and reused in other contexts. The use of MATLAB to animate the basketball shots provides some evidence of 'modification'. The visualisation of the shot is transformed from 2 dimensions to 3 dimensions. This helps the students make a connection between the mathematical model and the real world activity of shooting a basketball.

From the teacher's perspective the technological skills required to perform the curve fitting and the 3D animation are very manageable. This is because the curve fitting can be carried out by entering coordinates into row matrices using single line commands followed by selections from an interactive drop-down menu. The program that is required for the 3D animation is provided and only needs to be adapted by inserting a quadratic expression in a syntax similar to that used in a spreadsheet formula.

Conclusion

The mathematical investigations referred to in this paper have been analysed with reference to the Dimensions of Learning framework and shown to be suitable for secondary school mathematics students. The tasks have also been examined in relation to the SAMR and TPACK models for technology integration. This examination has shown that the tasks have been enhanced and transformed by the use of MATLAB without placing any great demands on the technological, pedagogical and content knowledge of secondary school mathematics teachers. From all of this it can be concluded that MATLAB can be used effectively in secondary school mathematics investigations.

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