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The Impact of Technology Use on Mathematics: Generating a Learning Model

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ABSTRACT

The outcomes of a comparative, multiple cases study on the use of different technology environments in mathematics learning led to the generation of a learning model for assessing technology use. This model proposes a framework for employing IT in the teaching and learning process. Here, I refer to the learning theory behind the model and describe its origins. I discuss in detail the model application in mathematics learning. Further, I point out to the different uses of the model in mathematics and other disciplines with, or without, technology.

KEYWORDS: *Technology environments, Learning approaches, Mathematics skills*

INTRODUCTION

The investigation of the theory of learning, in general, and mathematics learning, in particular, together with the examination of case studies on the impact of technology use on mathematics learning and doing as well as the current study case studies analysis and outcomes, could lead to the development of a learning model. This learning model, which is actually based on the interactions among Learning Approaches (LA), Mathematics Skills (MS) and Technology Environments (TE), is presented and discussed in detail in this paper.

Marton and Saljo (1976) identified two distinct ways in which students at university level approach reading comprehension. The first way involves a surface approach to learning where students adopt rote learning to accomplish the task given, aiming to finish as soon as possible. The main characteristic of surface learning is that learners do not actually understand the subject at hand. The second strategy identified by Marton and Saljo is the deep approach to learning. In this case, learners aim to look for meaning and use techniques such as wide reading, discussion and reflection. Deep understanding of the subject is the main characteristic of the approach. The exact parallel between the application of the deep and surface approaches to reading comprehension with problem solving reported by Laurillard (1997) was also presented. Further, the study reported by Ruthven (1990) is of great interest for the current study origins since it provides solid evidence about the use of graphic calculators on MS development and more importantly, it links rich technology environments with a positive change on the way students approached mathematics problem solving.

MODEL BACKGROUND

In an attempt to examine the possible application of LA dichotomy in mathematics, reported research on MS development is now discussed.

Galbraith and Haines (2001), propose a taxonomy including three key developmental skills in increasing order, required in the application and understanding of pre-university and on entry to university mathematics. These skills are described as:

- *mechanical*: systematic application of basic knowledge or procedures
- *interpretive*: put together information in order to reach a conceptually based conclusion
- *constructive*: creation of links between concepts and procedures that must be generated by the student as part of the solution process.

The authors report the construction, application and analysis of a test instrument (questionnaire) to 423 students in 1994-1996. The questionnaire included mathematics items in terms of the mechanical, interpretive and constructive categories. Results showed that the instrument used is robust and that the three levels taxonomy is effective. This means that the Galbraith and Haines developmental skills offer a suitable instrument in identifying mathematics understanding.

Related with the MS defined by Galbraith and Haines (2001), is the skills taxonomy (MATH) developed by Smith et al. (1996), in their report presenting ways of constructing formal undergraduate mathematics examinations which assess a range of knowledge and skills. This detailed skills assessment is also a useful guide for identifying the level of mathematical ability in the current study. Again, the students involved in the Smith et al study were involved in mathematics undergraduate programmes including technology use. This relates TE with mathematics learning and implies a possible link between technology use and MS development. The categories of the Smith et al. (1996) taxonomy are separated in three groups and are in parallel with Galbraith and Haines (2001) skills taxonomy.

From the discussion so far, it is more likely that surface and deep approaches to learning (Marton and Saljo 1976) relate to the development of mechanical, interpretive or constructive skills (Galbraith and Haines 2001) as well as to the MATH taxonomy group categories (Smith et. al 1996). For example, the adoption of a surface approach to mathematics learning is linked to the development of mechanical skills. In this case, the learner tries to apply what is already known, without making any effort to better understand the given task; the learner applies mathematics procedures by rote learning. The adoption of a deep approach to learning, on the other hand, is linked to the development of interpretive and constructive mathematical skills. The learner makes efforts to reach a conceptually based conclusion, links past mathematics concepts and knowledge with the current problematic situation in order to come to a solution.

Given that the theory of LA is mainly based on studies linked to literacy (Marton and Saljo 1976), it is significant to consider their viability in more quantitative fields. Mathematics is a good example because it can be either stand on its own, or, included in other practical areas like science and engineering. Laurillard (1997) takes the view that problem-solving tasks in science, mathematics and technology are seen as an important part of students' work because they test and reinforce their real understanding of what they have learned. Moreover, Biggs and

Telfer (1934, p.149) refer to the wide application of deep and surface approaches in education by stating that:

> *The notions of surface and deep approaches to learning have been found to have a very high generality; instances may found at primary school or at university, in particular tasks (such as essay writing, reading or problem solving) or a student's typical approach to academic learning in general.*

In an attempt to identify the interactions of learning approaches and mathematics understanding when technology is used, I introduce a model based on: (a) approaches to learning, and (b) doing mathematics.

The L.A.M.D.A. (Learning Approaches and Mathematics Doing Application) model (Figure1) aims to identify possible relationships between LA and MS interaction within TE. As discussed above, this is strongly connected to Galbraith and Haines (2001), Smith et al. (1996) as well as Ruthven (1990) reported research. In the first two cases, researchers identified advanced mathematics skills in environments related to technology use, whereas in the case of Ruthven the issue of learning approaches enhancement within technology mathematical environments is also raised.

But as a learning model, L.A.M.D.A. model is considered to be applicable in different learning environments in a number of learning contexts, like for example distance learning. Therefore, the model concept has to do with TE but can be of a wider application as well. In other words, the model is the most important aspect of the whole concept, being a necessary and sufficient condition to work.

The main innovation and primary usefulness of the LAMDA model though, focuses on gaining more insights on assessing the quality of mathematics learning in mathematical TE. Model origins and interactions are observed and discussed within mathematical TE. Both MS and LA were identified in this thesis in examining technology based case studies as well as in analyzing the pilot and fieldwork data.

LAMDA MODEL

I now focus on the model itself. Is LAMDA model appropriate for testing technology impact on mathematics learning? Would the model be applicable to evaluate mathematics learning in general? What does it bring to the researcher, the learner and the teacher? 'Doing mathematics' and 'learning approaches' are the basic dimensions of the LAMDA model. 'Doing mathematics' refers to the skills required for the application and understanding of mathematics, as defined by Galbraith and Haines (2001) and Smith et al. (1996). 'Learning approaches' refers to the application of surface and deep approaches to learning (Marton and Saljo 1976). The achieving approach to learning is not included in the model since it refers to cases of shifts between surface and deep approaches (Biggs and Moore 1993).

Figure 1 consists of three circles and three arrows. The circles represent the three starting points of the model (LA, MS, MATH) and the arrows represent the interactions between them. In order to unfold relationships the LAMDA model concept is presented in two diagrams; one for surface approaches (Figure 2) and one for deep approaches (Figure 3).

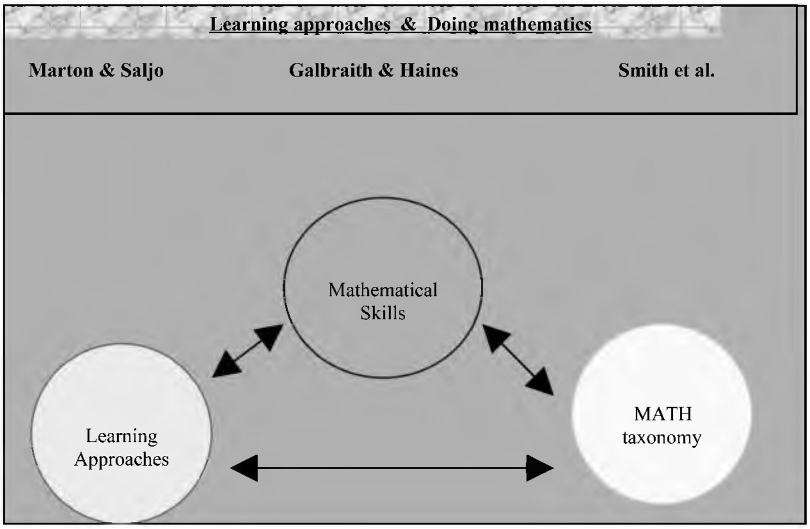

Figure 1: *Model origins*

Figure 2 presents the interactive relationships (double arrows) between:

- surface approach and mechanic skills
- surface approach and factual knowledge, comprehension and routine procedures
- mechanical skills and factual knowledge, comprehension and routine procedures.

Are surface LA directly linked to mechanical skills and first group categories of the MATH taxonomy? Are mechanical skills in parallel with factual knowledge, comprehension and routine procedures?

The application of this part of the model in neutral and mathematical TE might provide evidence for the impact of specific computer applications on a common and wide basis.

To further clarify this, think of the circles in the diagram as buttons. *What happens if we press the surface LA circle? Are the other two circles automatically generated? If the answer is positive, does this apply in different TE?*

There is evidence in the current research that neutral TE are consistent with surface approaches to mathematics learning and mechanic skills demonstration. MS identification also showed that mechanic skills are directly linked to factual knowledge, comprehension and routine procedures. Therefore, it is more likely that the first part of the LAMDA model applies in neutral TE.

Further, the generation of mechanic skills and first group descriptors of the MATH category seems to be valid within surface approaches regardless of TE, since no such skills were identified within deep approaches. This implies the application of this part of the model to different learning environments as well as different learning contexts. Further research is needed to justify this claim.

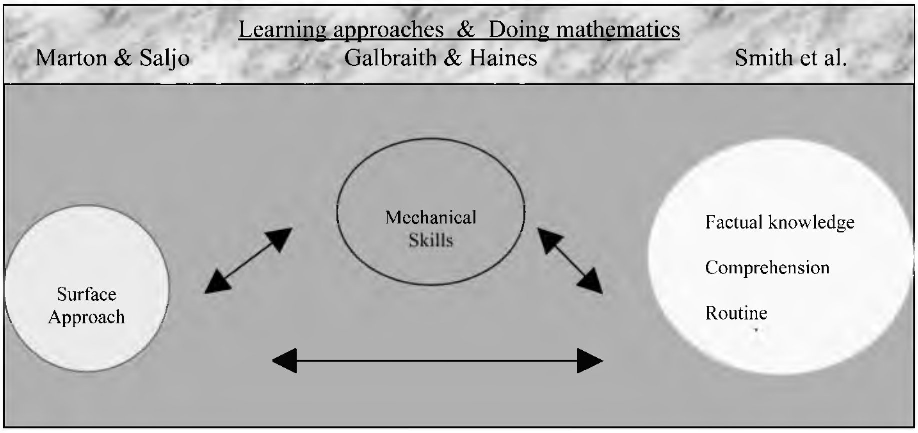

Figure 2: *Surface approaches model*

Figure3 presents the interactive relationships between:

- deep approaches and interpretive skills
- deep approaches and constructive skills
- deep approaches and justifying and interpreting, implications, conjectures and evaluation
- deep approaches and information transfer and application in new situations
- interpretive skills and justifying and interpreting, implications, conjectures and evaluation
- constructive skills and information transfer and application in new situations.

In other words, the second part of the model shows the direct interactions of deep LA with interpretive and constructive MS as well as with the second and third groups of MATH taxonomy. It also demonstrates the parallel relations between interpretive skills and justifying and interpreting, implications, conjectures and evaluation, on one hand, and constructive skills and information transfer and application in new situations, on the other.

Ideally, the model introduced in this study might provide a useful instrument for: (a) researchers to examine the impact of different tools on mathematics learning, (b) teachers to assess learning in different learning environments and (c) learners to promote skills strategies related to deep understanding.

An important contribution of the current study to researchers, teachers and learners is the generation of a learning model (L.A.M.D.A. model). This model is based on the interactions between learning approaches and skills development. The categorisation of the skills included in the model is based on mathematics learning research and experience but could also refer to learning in general. Hierarchical skills development can be linked to any area of learning. Deep and surface learning approaches also included in the model are more likely to be adapted to any kind of learning. In other words, approaches and skills interaction and development are more likely to be applicable to a wider concept of learning. LAMDA model therefore, could be applied to different subject areas and different learning environments to assess the quality of learning.

More interesting, I believe, is the application of the model as a tool for assessing technology use in mathematics learning. The wider concept on which the model was generated might also be used as the basis for the development of similar models for assessing technology use in other disciplines. Thus, LAMDA model might be considered as an assessing tool for learning with technology in a variety of fields. Further research is needed to test the validity of LAMDA model in mathematics in particular and learning in general. Further research is also needed to justify the application of learning approaches and/or skills categories in different disciplines.

MODEL APPLICATION

LAMDA model was applied in a study including 316 participants. The aim of the study was to examine the impact of technology use on mathematics learning. The 316 participants came from England and Cyprus. They were separated in four groups: undergraduate students at an English University (E1), adult students at an English University (E2), undergraduate students at Cyprus University (C1), and middle school students at three Cypriot Lyceums (C2). The model was used as an assessing tool for mathematics understanding when technology was in place in each of the four groups. Results showed that:

- Neutral technology environments are consistent with surface approaches to mathematics learning and mechanic skills demonstration.
- Rich technology environments are consistent with deep approaches to learning and constructive skills demonstration.
- High ability students from poor technology environments followed a deep approach and demonstrated constructive skills.
- In depth programming use was found to be closely related with constructive skills development.
- Technology misuse was found in cases of surface learners with low mathematics ability that came from neutral technology environments.
- Past experience in doing mathematics influences both learning approaches development and mathematical skills demonstration.

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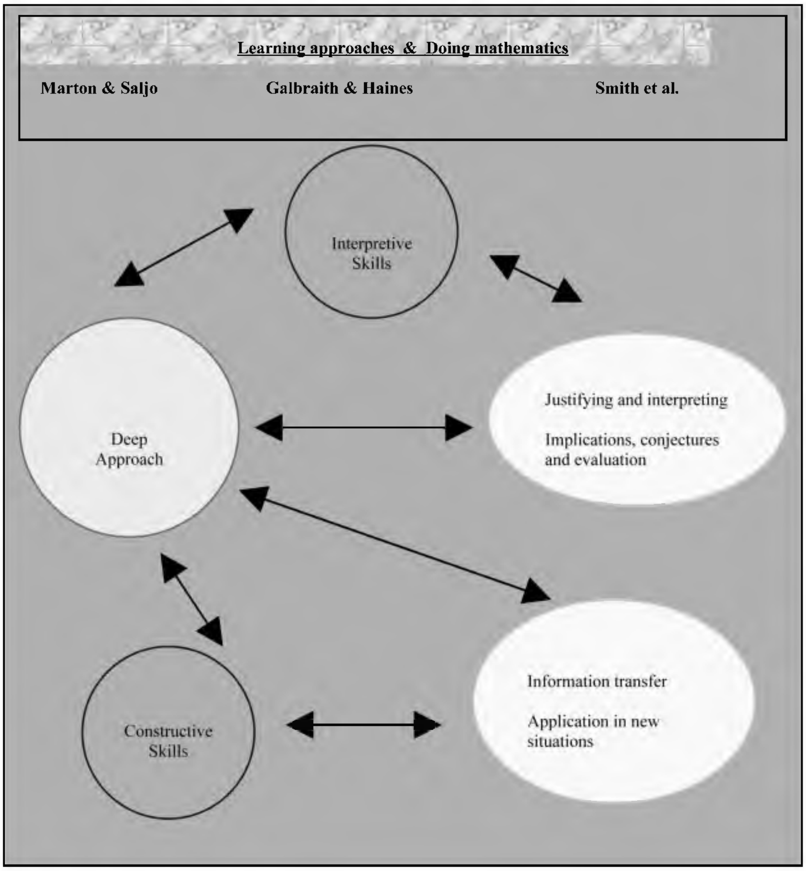

Figure 3: *Deep approaches model*

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