

GRAPHICS CALCULATORS INTEGRATION INTO CURRICULUM

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Introduction

The effects of graphic calculators on the teaching and learning of mathematics depend on how this new technology is integrated into the curriculum. Current research shows that graphic calculators can enhance the learning of functions and graphing concepts and the development of spatial visualization skills (Penglase and Arnold, 1996). However, most studies do not give detailed information on the way the calculators were integrated into the curriculum. Three main integration phases are proposed: introduction, adaptation and consolidation. Each phase is characterized by the way the calculators are used by the students and the teacher, by the type of tasks that are done by them or proposed by the textbook and by the role played by graphic calculators in assessment. These integration phases depend strongly on how mathematical knowledge is seen by the different pedagogical agents and on the visions that the institution, the teacher and the textbook have on teaching, on learning and on the role of the graphic calculator in those processes. Results from a study presented here show the importance of taking into account these integration phases. An analysis is made on the way mathematical knowledge can be approached depending on how the technology is integrated into the curriculum.

Graphics calculators integration into the curriculum

Graphics calculators cannot be simply introduced into the curriculum. They can be used at different levels and can have different roles in curriculum design and implementation. The effects of using graphics calculators can depend upon how they are integrated into curriculum. Following the ideas suggested by Kissane, Kemp and Bradley (1996) for assessment and graphics calculators use, we introduce four phases concerning graphics calculators use in curriculum design and implementation: non-existent, introduction, adaptation and consolidation. We consider five elements of the curriculum: students' use, teachers' use, tasks proposed, textbook, and assessment. Each of these elements can be in any of the four phases. The first phase is evident: graphics calculators are not used or mentioned at all. Table 1 shows how each of the three other phases is defined on the basis of the curriculum elements considered.

The main difference between the adaptation and the consolidation phases concerns whether advantage is taken of the graphics calculator possibilities. This means whether graphics calculators are used in order to create new learning opportunities through promoting mathematical investigation and exploration and emphasizing relationships among representation systems. The above categories do not take into account the way graphics

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	Phases		
	Introduction	Adaptation	Consolidation
Students	Students have restricted access during some classes. They do not have access outside the classroom.	Students have unrestricted access to graphics calculators.	
Teacher	The teacher has a basic knowledge about the graphics calculator operation. He/she does not use it during classroom activities at all, except for explaining how to use it.	The teacher uses the graphics calculator when it is necessary or when asked to do so by the students. His/her explanations do not take advantage of graphics calculator possibilities.	The teacher takes advantage of the graphics calculator possibilities for explanations and problem posing.
Tasks	The only tasks that involve the graphics calculator are those used to learn how to use it.	Few tasks take advantage of the graphics calculator possibilities.	Most tasks take advantage of the graphics calculator possibilities.
Textbook	Reference is made to graphics calculator as far as how to use it. Problems and exercises do not take advantage of the graphics calculator possibilities.	Some problems and exercises are specially designed for graphics calculators use. The way content is presented and learning is promoted do not take advantage of the graphics calculator possibilities.	Problems proposed and the way content is presented and learning is promoted take advantage of the graphics calculator possibilities.
Assessment	Graphics calculators are not allowed in tests.	Questions are “calculator-neutral”. There is no advantage to students with a graphics calculator.	Unrestricted calculator access. Students decide when and how to use the graphics calculator.

Table 1: Integration phases

calculators are used by teacher and students when presenting an explanation or solving a problem.

These categories are proposed in order to classify curriculum innovations that involve the use of graphics calculators. It is clearly possible for a given curriculum innovation implementation to be located in different phases for different elements of the curriculum. This can be the case, for example, when teacher’s use of the graphics calculator remains at the

introduction phase, whereas curriculum design imposes conditions for graphics calculators use at the adaptation phase on the other elements. In this sense, the teacher plays an important role in the process. This can also be the case concerning assessment. If assessment remains at the introduction phase, the effects of graphics calculators use might be curtailed even if other elements are at the adaptation phase. Nevertheless, even if no curriculum innovation can be accurately classified in one level, it seems reasonable to think that most elements will adjust themselves so that they are approximately at the same phase.

Graphics calculators use in Precalculus and achievement in Calculus

A study was done concerning the effects on students' achievement on calculus of graphics calculators use in a precalculus course. We wanted to see whether students that had taken a precalculus course involving a curriculum innovation that included graphics calculators use could obtain better results in the second calculus course of the mathematics cycle (in which there was no graphics calculators use), when compared with other students who took the standard precalculus course. Additionally, we were interested in seeing whether the effects of graphics calculators use depended upon the phase at which the technology was integrated into the curriculum.

The established precalculus course is an introductory course to the study of functions in which some emphasis is given to the graphical representation and to problem-solving. Usually the teacher presents some theory at the beginning of the lecture, and the rest of it is spent solving exercises with some students at the blackboard. The curriculum innovation involving graphics calculators use introduced some changes to this precalculus curriculum. A stronger emphasis was given to the connections between the symbolic and the graphical representations and the concept of family of functions was introduced. Lectures were mainly developed around problem solving activities (Gómez et al., 1996) that followed the ideas of higher-order mathematical thinking (Resnick, 1987). Graphic calculators are not allowed in the two calculus courses that follow the precalculus course. In these courses students are expected to develop operational skills for symbolic manipulation. Lectures are taught in a similar way to the standard precalculus course.

The curriculum innovation involving graphics calculators use underwent the three phases (introduction, adaptation and consolidation) described previously. The three phases were developed during three consecutive semesters. Some results are already known concerning this curriculum innovation. Mesa and Gómez (1996) found no differences in some aspects of understanding between the students who took the traditional course and those who took the curriculum innovation at the adaptation phase. Gómez (1995) and Gómez and Rico (1995) found that the students of this group participated more actively in social interaction and in the construction of the mathematical discourse, changes that can partially be attributed to a different behavior of the teacher. Even though she changed her behavior, Valero and Gómez (1996) found that the teacher could not change completely her beliefs system. Finally, Carulla and Gómez (1996) found that the teachers and researchers who participated in the curriculum innovation (at the adaptation and consolidation phases) underwent significant changes on their visions about mathematics, its learning and teaching.

Results

The design and the results of this study are discussed in detail in (Gómez and Fernández, 1997). The results show that the effects of graphics calculators use in this study depended directly upon the phase at which graphics calculators were integrated into the curriculum. While no significant difference was observed between the calculators and non-calculators groups when the curriculum innovation was at the adaptation phase, significant differences were found between these two groups at the consolidation phase, and between the calculators groups of the adaptation and consolidation phases. This might be due to the fact that during the consolidation phase, graphics calculators were used to create new learning opportunities through the promotion of mathematical investigation and exploration and the emphasis given to the relationships among representation systems. Furthermore, these differences (specially those concerning the two teachers that participated at the two phases) might also be explained by the change that teachers and researchers had of their visions about mathematics, its teaching and learning as a consequence of the way graphics calculators were integrated into the curriculum (Carulla and Gómez, 1996). These results show that, at least as far as achievement is concerned, graphics calculators effects cannot and should not be studied independently of the way the new technology is integrated into the curriculum. Furthermore, it might be possible, as it was the case for the experience reported here, that the use of graphics calculators needs to go through an “integration process” in which in order to attain a given phase, the previous phases have to be completed. It remains to be seen whether a successful consolidation phase (as far as achievement is concerned) can be attained without a change in teachers’ visions.

Discussion

The results presented here support a view according to which success in introducing graphics calculators into the curriculum might depend on the way its integration process takes place. There might be important differences depending on whether graphics calculators integration into the curriculum attain the consolidation phase or not. Furthermore, whether the integration process can attain this consolidation phase might depend on whether curriculum designers and teachers can take advantage of the graphics calculators presence in order to work with new ways of seeing the mathematical knowledge to be taught, the way it can be learned, the way it should be taught and the role graphics calculators can play in this process.

For some teachers and students knowing mathematics means to know a set of procedures (algorithms) that transform some symbolic expressions into others, being able to recognize to which expressions and when an algorithm can and should be applied, being able to recognize which algorithms can be applied to a given expression, knowing a valid form of the algorithm that is to be applied, and applying it properly. In this case, mathematical knowledge will be seen as a set of symbolic expressions that can be transformed syntactically, and a good teacher would be that one who teaches algorithms, who is able to make the students remember and apply them properly, and who assesses students accordingly. When this happens, then it would be very difficult to attain the consolidation phase of the graphics calculators integration process into curriculum.

It could be argued that in order to attain the consolidation phase it is necessary for teachers and students to have a different view of mathematics and the way it is to be taught and learned. Mathematical objects should exist for the students, as connected internal representations, in such a way that they can be “seen” from multiple representation systems. The students should be able to “see” a mathematical reality which is independent of the teacher’s authority and that can be socially constructed.

However, it is not necessary for students and teachers to have these views before using graphics calculators. Graphics calculators use can be an important factor for developing them. This should be a dialectical process in which graphics calculators integration into curriculum and the development of new views of the mathematical knowledge to be taught support each other.

References

- Carulla, C., Gómez, P. (1996). Graphic calculators and precalculus. Effects on curriculum design. In Puig, L., Gutiérrez, A. (Eds.). *Proceedings of the 20th PME Conference*. Valencia: Universidad de Valencia, pp. 1-161.
- Gómez, P. (1995). *Interacción social, discurso matemático y calculadora gráfica en el salón de clase. Una aproximación experimental*. Bogotá: Universidad de Granada y una empresa docente.
- Gómez, P., Fernández, F. (1997). Graphics calculators use in precalculus and achievement in calculus. En Pehkonen, E. (Ed.) *Proceedings of the PME 21 Conference*. Lahti: University of Helsinki, pp. 3.1-3.8.
- Gómez, P., Mesa, V.M., Carulla, C., Gómez, C., Valero, P. (1996). *Situaciones problemáticas de precálculo. El estudio de funciones a través de la exploración con calculadoras gráficas*. México: una empresa docente y Grupo Editorial Iberoamérica.
- Gómez, P., Rico, L. (1995). Social interaction and mathematical discourse in the classroom. In Meira, L., Carraher, D. (Eds.). *Proceedings of the 19th PME Conference*. Recife: Universidade Federal de Pernambuco, pp. I-205.
- Kissane, B., Kemp, M., Bradley, J. (1996). Graphics calculators and assessment. In Gómez, P., Waits, B.K. (Eds.). *Roles of calculators in the classroom [On-line]*. Available: <http://ued.uniandes.edu.co/roles-calc.html>.
- Mesa, V. M., Gómez, P. (1996). Graphing calculators and precalculus: An exploration of some aspects of students’ understanding. In Puig, L., Gutiérrez, A. (Eds.). *Proceedings of the 20th PME Conference*. Valencia: Universidad de Valencia, pp. 3.391-3.399.
- Penglase, M., Arnold, S. (1996). The graphics calculator in mathematics education: A critical review of recent research. *Mathematics Education Research Journal*. 8 (1), pp. 58-90.
- Valero, P., Gómez, C. (1996). Precalculus and graphic calculators: The influence on teachers beliefs. In Puig, L., Gutiérrez, A. (Eds.). *Proceedings of the 20th PME Conference*. Valencia: Universidad de Valencia, pp. 4.363-4.370.