COMPUTER SOFTWARE AS A HELP PROVIDER TO STUDENTS UNSUCCESSFUL IN MATHEMATICS

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Summary

We believe that computers can be used to increase the level of success only among such university students who had acquired necessary mathematical skills, basic computer skills and skills relevant to the respective software, and whose level of English is appropriate. In the contribution we give an example of solving a task common in the basic course of mathematical analysis by means of Maple and outline problems, which occur in this respect.

Key words

Prospective teachers' mathematical training, study failure, help-seeking, computer, Maple

Introduction

The issues of learning success at respective grades and types of school and the search for reasons of school failures, bad school results or learning troubles have been constantly monitored and analysed from many points of view. They have been studied and described in a number of empirical researches – both pedagogical and psychological ones. The discussion has resulted in a number of quantitative outcomes, surveys and graphs of respective study programmes and fields of study and in school annual reports and registers.

In our contribution we are going to give several notes from the field of university training in mathematics. It is a well known fact that mathematics present in university curricula is

- a set of specific subjects, usually theoretical ones, which are the scientific content of study (at faculties of science or mathematics and physics) or
- a set of propedeutically oriented disciplines, which provide necessary content and teach necessary skills at universities of technology or faculties of economics or
- subject base at universities training prospective teachers of mathematics.

Our experience has been acquired both from students of mathematics at faculties of education and from students at universities of technology. These students have – despite a number of differences – a lot in common. They share low incoming level of mathematical competence or the fact that theoretical mathematics plays a minor (if any) role in their professional lives after graduation. They also share the fact that they work with information technologies at various levels and in various forms during their university study – a time of shaping and cultivating their characters.

Some general (theoretical and methodological) starting points

As can be seen e.g. from Skalková (1999), Jaworski (1994) pedagogy has redefined the roles of a teacher and a student. The original role of a teacher as a person who teaches students in direct contact and gives them access to his/her knowledge base has transformed into a role of a facilitator who helps, mediates or facilitates the process of study. This invites students to use other sources of information and makes them be active. As some authors – e.g. Fulier (2005), Majovská (2007) – point out, passive reception of knowledge results in mathematics being viewed in a deformed way – as a set of unnecessary, incomprehensible, irrational recipes or algorithms which are not needed or required by anybody (with the exception of the teacher or examiner). Computers not only eliminate or limit arduous and routine calculations but according to some – e.g. Brdička (2003) – they can act as accelerators emphasising a number of teaching methods. The article by Uhlířová (2006), gives an overview of roles of computer in the teaching process. In our contribution we are going to make use of the role of an electronic teacher (closed teaching environments which lead the student, direct and evaluate their learning process) and the role of experimental environment for formulating and verifying hypotheses (in the sense of cognitive and open teaching environments such as computer software Maple, Derive, Mathematica or MATLAB). Computer software can be "taught" to provide help in study and to be infinitely patient when a student is trying to solve mathematical tasks and problems.

The issue of providing help in study when solving tasks and problems in the area of psychology is dealt with in Mareš (2002). The author stresses that help-seeking by a student or a pupil can be interpreted also positively as help-seeking indicates interest in finding a solution and enables prevention of failures. Help-seeking starts with a stage of perplexity, when a student realises the difficulty of the situation and its complexity and is perplexed as there are no obvious solutions or strategies of solution. The student faces the contradiction between what he knows or is capable of doing and what is asked of him. The author gives several typologies and models of help-seeking:

- according to the level of orientation of the person (student) who is facing the problems: the effort to seek external help or the effort to avoid help-seeking,
- according to the way of communication with the potential help provider: verbal, nonverbal or mixed communication,
- according to the result expectations: help-seeking accompanied by the feelings of low, medium or high probability of success,
- according to the type of help provider: seeking help from a human being (teacher, schoolmate, etc.) or a machine (computer, computer software, multimedia device).

Given results of some foreign researches Mareš concludes that situations when students learn by the means of computer and communicate with teachers or other students in real time encourage help-seeking.

The topic of success at study and its subjective reflection (subjective interpretation) is closely connected to factors of social motivation. The social psychology is aware of the model of Weiner (1985), which is sometimes called attributive theory of success and failure. Weiner suggests that our motivation to reach success is determined by our perception of previous successes and failures. He believes that perception of reasons (casual attribution) can be viewed from the point of view of reason localisation (internal or external), reason stability (permanent or temporary) and reason controllability (the subject controls the reason or not).

An interesting attempt to apply the attributive theory in the area of failure at mathematical exams has been done by Marcinek (2005). The author reduces the factors intervening in casual interpretation into locus and stability and obtained the following 4 typical authentic student responses:

Tab. 1 *Typical authentic student responses according to (Marcinek, 2005).*

		Reason locus (position)	
		External	*Internal*
Reason stability	*Unstable*	I totally messed the exam up. We were short of time, there were exercises we had never seen before.	I don't know what was going on with me. I didn't feel well, I may have a fever. I hope, I'll be able to correct the mark.
	Stable	I can never be good with N.; no matter what I count, he would give me a bad mark.	Failed again! I'm totally stupid, I'll never learn it!

Computer and linguistic competence as a pre-requisite of providing help by means of computer software

The psychological aspect, some features of which have been given or discussed above, is only a part of the set of pre-requisites necessary for meaningful use of computer software as an assistant in overcoming failures during study. More pre-requisites have to be regarded:

- basic mathematical and computer literacy of the student (user) – in the sense of effective use of possibilities offered by the software with a reasonable level of user comfort; this is a pre-requisite of not only finding a solution of the task but also of its correct (mathematical) interpretation,
- necessary linguistic competence enabling communication with the software in English.

We have studied these issues among students of Palacký University in Olomouc and Brno University of Technology since 2005/6. Some partial results of this research have been published by Novák, M. beginning with Novák (2005). The results confirm generally low level of linguistic and communicative competence of students in English, which to a great extent limits the use of computers in providing help in study. For example a great part of students of Faculty of Education, Palacký University suggests that work with texts in English in mathematical subjects (the teaching itself would be carried out in Czech) would mean great (71 %) or even insuperable (12 %) problems (responses to a questionnaire carried out among students of *Teaching mathematics at lower secondary schools* study programme in 2005/6).

Solving a mathematical task using Maple

Let us now demonstrate the importance of the above mentioned pre-requisites using an example all students of mathematics oriented study programmes come in contact with - the task of establishing the course of a function, which is a typical task solved during the introductory basic course of mathematical analysis. It is usually a climax of the course as when solving the task students have to apply knowledge obtained throughout the course.

Solving the task by means of Maple (in this contribution Maple 9.5, Classic Worksheet, which is a low enough version to be universally used, yet it is not obsolete) is easy – the following sequence is appropriate. Every first year student informed about basics of Maple and capable of using it should be able to prepare such a sequence either on their own or in a pair or a small group either during a computer class or as homework:

Fig. 1 *Sequence of Maple commands*

```
[> restart:
[> y:=1/(x^2-6*x+8):
[> pos:=solve(y>0): neg:=solve(y<0): zero_points:=solve(y=0):
[> first_derivative:=simplify(diff(y,x)):
[> increasing:=solve(first_derivative>0): decreasing:=solve(first_derivative<0):
[> stationary_point:=solve(first_derivative=0):
[> second_derivative:=simplify(diff(first_derivative,x)):
[> concave_up:=solve(second_derivative>0): concave_down:=solve(second_derivative<0):
[> inflexion:=solve(second_derivative=0):
[> subs(x=stationary_point,second_derivative):
[> Limit(y,x=2,right)=limit(y,x=2,right): Limit(y,x=2,left)=limit(y,x=2,left):
[> Limit(y,x=4,right)=limit(y,x=4,right): Limit(y,x=4,left)=limit(y,x=4,left):
[> k1:=limit(y/x,x=infinity): Limit(y/x,x=infinity)=k1:
[> q1:=limit(y-k1*x,x=infinity): Limit(y-k1*x,x=infinity)=q1:
[> k2:=limit(y/x,x=-infinity): Limit(y/x,x=-infinity)=k2:
[> q2:=limit(y-k1*x,x=-infinity): Limit(y-k1*x,x=-infinity)=q2:
[> asymptote1:=k1*x+q1:
[> asymptote2:=k2*x+q2:
[> plot(y,x=-infinity..infinity):
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Two important questions occur in this respect:

- Who is going to prepare this sequence, which is going to be used to solve other tasks of the same type: a teacher or students?
- How are students going to use it when solving other tasks of the same type?

A questionnaire research among 245 first year BUT students gave the following result: the idea that such a sequence of commands as has been mentioned above should be prepared by students themselves was favoured by less than 10 % of students. Most students assume that the above sequence is prepared by the teacher – 47 % of students expect the ideal form of a computer-aided class to be changing values of some variables in such sequences, which in our case means changing the function in question. Further 59 % students expect to use such example files to solve specific exercises (which in this respect coincides with the former option).

This means – after certain generalization – that an important part of students finds being passive users, or rather "passive receptors" in the terminology of Lenke (2008), natural and assumes using a tool which they had not prepared (even though they are able to prepare it). They do not know the true nature of the tool, or rather find knowing it unimportant and redundant.

Students as passive computer users

Let us accept the idea of students – passive users or "passive receptors" and let us try to simulate their work with the above mentioned sequence of commands solving the tasks of establishing the course of a function. Let us assume a function $f(x) = 1/(x^2-6x+8)$. We want to find all the usual data: domain and codomain, sign, intervals of monotony, local extremes, intervals of concavity / convexity, inflection points, asymptotes and the graph of the given function. When solving the task students can meaningfully use a computer only when they had acquired necessary mathematical, computer, and linguistic competence. We are going to show this using several examples. The last command in the sequence is an obvious case. We draw the function on $(-\infty, \infty)$ but the acquired graph is naturally useless if the student is not aware of the interval to which he/she is supposed to restrict the graph. The student further needs to know if constrained or unconstrained view is better for the given function and has to deal with points of discontinuity. This, however, assumes basic level of computer as well as mathematical literacy of the student as they need to know which parameter to change and how to change it.

Fig. 2 *Possible form of results*

$$pos := \text{RealRange}(-\infty, \text{Open}(2)), \text{RealRange}(\text{Open}(4), \infty)$$
$$neg := \text{RealRange}(\text{Open}(2), \text{Open}(4))$$
$$zero\_points :=$$

Solving equations or inequalities is used throughout the sequence. Their solutions offered by Maple have the form as in Fig. 2. Students can interpret it correctly only if they have such knowledge of mathematics as to be able to assign some meaning to the results. Why are all the intervals in the figure open? What about points 2 and 4? Moreover, the student should know how to interpret the result on the last line (such a point does not exist or is there a mistake in the task?), which again assumes basic knowledge about the software the student is working with. The function used as an example has one stationary point. If the student chooses a function with more stationary points, performing the respective command results in an error. From the programmer's point of view this is natural as the student substitutes a variable of other than expected type. Yet what will be the response of a student, who had not prepared this sequence and who does not have appropriate experience in using the software? Will the student be able to correct the error, i.e. to understand the text of the error and subsequently find the relevant commands and their syntax in English written help if his/her level of English is not satisfactory? Experience coming from Novák & Langerová (2006), which deals with Matlab, however, does not suggest high level of expected success. When looking for asymptotes we use variables asymptote1 and asymptote2. Correct interpretation of its values again assumes certain level of mathematical knowledge. Students should be ready to interpret the fact that their values are equal, are not equal, or that one of the values is or contains infinity. When looking for the vertical asymptotes students should be ready to tell the points in which the given limits are to be computed, i.e. they should be aware of the connection to the domain of the given function.

Let us conclude with the greatest risk which the student without necessary mathematical skills may face during computer aided practical classes. Meaningless changing of values or parameters may lead a student – passive computer user to totally wrong conclusions. If unable to assign mathematical sense to any of the interim results, or rather if unable to guess at least approximate results or their possible form, students can invoke an arbitrary result or arbitrary non-standard behaviour at an arbitrary place. A student – passive user with insufficient knowledge of mathematics cannot realise that values of variables or parameters had not been reset and takes the out coming results for granted, even though they are evidently wrong or even nonsensical. It is the belief that the values computed by a computer must be correct that is to be blamed.

Conclusion

We agree with the often suggested notion that implementing new technologies into teaching mathematics at all grades and types of school follows two interrelated aims:

- to make things, which have to be done anyway, easier both for the student and for the teacher, to help to understand nature of things and processes, to reach the principles of problems faster, more clearly and in a more effective way,
- to change the nature of education, in which new motivational environment with an easy and easily accessible offer of information, which the learner can use in a flexible and creative way, is to play a dominant role.

These aims can be accomplished only under certain conditions, some of which we have included in our contribution. A computer may provide help only to a student who does not willingly act as a passive user but has some experience in using the software and such knowledge of mathematics, which enable him to assign mathematical sense to acquired results, instead. If these conditions are fulfilled, a machine, or rather computer software can be a useful tool for higher level of success during studies of mathematics not only at universities.

In order to work meaningfully (not only to solve unexpected problems and situations) the student also has to have certain level of linguistic competence. If mathematical software is used repeatedly in an inappropriate way or for a longer period, a student – passive user with unsatisfactory level of English may very quickly form negative opinion as far as using mathematical software is concerned and may ignore it or reject using it in advance.

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