On-line tutorials in undergraduate mathematics

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Abstract: This paper concerns a blended learning environment in introductory undergraduate mathematics, where web-based training is integrated with classroom instruction. Such an environment is believed to be conducive to students' individual learning preferences. This paper examines students' experiences and needs, and compares them to a model of the student assumed by the on-line tutoring systems. Based on particular case studies I argue that regular practice using the on-line tutoring system may change the students' personal meaning of the learning activity and consequently change students' attitude and work habit towards higher level of industriousness and perseverance in their study. However, web-based training is less influential in terms of other aspects such as raising students' interest in the subject and teaching them to think mathematically.

Key-Words: Learning culture, personal meaning of activity, on-line practice, calculus, students' characteristics.

1 Introduction

The popularity of on-line tutoring systems has grown in recent years partly due to the continuous improvement of their design, the increasing selection of options they offer, their proven efficiency in evaluating students' work and providing instant feedback, especially for large classes.

Instructors believe that in learning mathematics, practicing exercises play an important role in understanding mathematical concepts. Consequently, this type of educational software becomes useful because it can randomize numbers in problems similar to those discussed in the textbooks, and thus provide the learner with virtually an unlimited set of problems related to a mathematical topic. In addition, the system generates an instant response to a student's input which presumably forces the student to review the incorrect answer until it is accepted by the system. Many systems also provide access to similar examples with detailed explicit or guided solutions, videos of related lectures and textbook chapters. The type of questions may vary from multiple-choice to those requiring an answer in numerical and algebraic form. The instructor has the option of selecting problems from the existing database or introducing her own questions. Usually, on-line tutoring systems claim a two-fold goal, they: (1) improve students' learning by giving them access to practicing the skills at their own pace, and (2) free up the instructor's time from marking which allows more time to be devoted to actual teaching.

The Department of Mathematics and Statistics at Memorial University is currently investigating the possibility of adopting a computerized assessment/tutoring system for introductory undergraduate courses. During 2007-2009 the software called MyMathLab was used in assisting several sections of a Precalculus course, which focused on algebra and trigonometry topics. In 2010-2011, software called WebAssign, was used for instruction of the first course in the calculus sequence. This report is based on feedback from teachers and students regarding their experiences working with the online tutoring systems.

Educational software can be considered from different perspectives such as domain and pedagogical expertise or the quality of the interface. The model of the student is one important characteristic yet to be taken into account [1]. When tutoring software is designed, there is a certain assumption about the student who ideally will benefit from it. In this paper, I argue that according to the model of the student presumed by the on-line tutoring software used to assist undergraduate students in mathematics, certain students' characteristics are desirable, if not vital, for the effective use of such software. The information collected from instructors and students helps us to understand the reality of the classroom where the software implementation takes place. I propose that

with an adequate control from the instructor the use of this software may also change students' learning habits through changing the meaning assigned by the students to the purpose of the activity. Even if the software fails to improve students' motivation to learn the subject, it still may contribute in teaching them how to organize and maintain their work on a regular basis.

Thus with all the flexibility offered by on-line tutoring systems, instructors have to make important decisions about the forms of assignment and the degree of sharing the labour between the software and themselves, aiming to create a local learning culture and provide a better learning experience for the students.

2 Making personal meaning of the activity

"Pupils accomplish educational activities by using what they know to make sense of what they are asked to do" [2]. Thus, the meaning which students assign to an activity can be understood as a condition for them to engage in learning and to act accordingly [3,4]. Vollstedt [5] follows Howson [6] in separating personal meaning from a collective meaning shared by a group of learners. Students ask themselves "what is the point of this activity for me?" and the answer to the question about the personal relevance of an action may often predict the success rate of their performance. It is proposed that "the construction of personal meaning is context bound" [7], and that the surrounding learning culture is one of the important aspects of the personal context [8]. Vollstedt [7] describes a 16 years old Hong Kong student Emma, who studies mathematics. While the student possesses "a low mathematics self-concept", she admits that "practicing mathematics soothes and prepares for important exam". The researcher identifies Emma's confession as being her personal meaning constructed while solving mathematical exercises. In addition, Emma asserts that "actively doing mathematics can help train us our mind and the logic." It is observed that "Emma's behavior is somewhat typical to Hong Kong students". The development of this personal meaning of doing mathematical problems and actions she carries out (practicing as much as possible) is attributed to the Confucian Heritage Culture (CHC) in Emma's case. In CHC rote learning, memorization, extensive practice, and extrinsic motivation (some 'push' in learning) are accepted as necessary steps of learning and they often are viewed as parts of the understanding and further comprehension processes [9,10].

One can see how Emma could clearly benefit from on-line tutoring software in learning mathematics. A learner who welcomes extra practice, handy resources, and a little 'push' in their study is the model of the ideal student that software developers apparently had in mind when they made the on-line tutoring software.

3 Interview with students

It is difficult to measure the effect of educational software on student's achievements due to many other factors contributing to the final result. Nevertheless, some intermediate data were collected and analyzed in [11]. The data indicates that the use of software may lead to a reduction of failure rates in mathematics. However, one would rather detect a positive shift due to the employment of on-line tutorials among students in the upper half of grade spectrum than in reduction of the failure rate. In addition, a study of mathematical intimacy, flow experiences and confidence of students, conducted by Radu & Seifert [12], indicate that incorporation of on-line tutorial system in pre-calculus teaching "may have a positive effect for some students and a negative effect for others."

In order to shed light on these phenomena, both instructors and students were interviewed. The instructors were asked to characterize their students and to predict how beneficial the use of this type of software would be for them. Instructors felt that if a student has solid background knowledge in high school mathematics, ability to learn independently, commitment to attend classes and do homework along with goal to do well in their courses, then such student will benefit from an on-line tutoring the most because they can practice and reflect on their work. For more details specifically about pre-calculus classes see [13].

In this section I examine more closely what happens at the individual students' level when they study calculus and use an on-line tutoring system. Two sections of Calculus were observed in 2010. The one I report on in this paper had the following set up: Twelve weeks of lectures, two midterms and a final exam. Written weekly assignments were collected and marked. On-line component contained 10 sets of questions recommended for weekly practice. An unlimited number of trials were allowed for students to complete the on-line exercises. Completion of all on-line problems due at the end of the semester warranted 5% of the total mark.

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Who were the students enrolled in a calculus class? A survey of 60 participants-volunteers (amongst 85 students enrolled in class) was conducted at the end of the semester, right before the final exam. It revealed the following characteristics.

- There were equal number of male and female students;
- Most students were about 18-21 years of age with very few older that 25;
- About a third of the group were taking Calculus for the second time;
- As for the students' goals, a quarter of the class sought "just to pass" the course, another quarter aimed to learn, and half of the class wanted to "get a good mark";
- The majority (87%) thought that the material they studied was challenging;
- About 82% of the students also thought that Calculus was interesting and may be useful.
- About 70% of the students anticipated an A or B mark in the course. (In reality 49 students out of 85 in this class received an A or B mark).

In order to understand the students' perspective, several interviews were conducted. Here I present responses from three female students Amanda (28), Brenda (18) and Cindy (18) (the actual students' names were changed). At the time of the interview all three students had already completed a Pre-calculus course and were in the second half of their Calculus course. These students responded to the call for volunteers to share their experiences. The only requirement was that respondents must have used an on-line tutorial system regularly during the semester.

The first group of questions was concerned with students' general experiences.

Talking with students, I learned that the classroom contained students of different ages, from different provinces and with different mathematical experiences. Brenda and Cindy were local students. They came to the university directly from high school. They completed the same high school math program and were of the same age. Amanda's background differed from theirs in many respects. She was from another province. Amanda had more solid preparation in high school mathematics, but after high school she worked for about ten years. Amanda was also a more mature and determined learner. Yet, all three students attributed a significant part of their positive mathematical experience to "having a good teacher".

Among reasons which made the study of mathematics problematic, Brenda identified "learning mathematics in French", which was not her first language, Cindy recognized the intrinsic difficulty of the subject, and Amanda seemed to be able to handle her studies successfully. All three students associated mathematics with solving problems and working through equations. At the same time Amanda mentioned logic, Brenda talked about "stressfulness and possible enjoyment" and Cindy pointed out the "endlessness" of the subject. It is not surprising that all three students associate the understanding of mathematics with the ability to solve problems without extra help. The "ability to explain" also indicates understanding for Amanda and Brenda but not for Cindy. All three students preferred to learn mathematics from examples and practice. Brenda emphasized the need to remember rules and formulas, but she also recognized that there was more that just memorization in learning mathematics. When asked about their passions and future careers, none of the three students chose mathematics. Their choices were: linguistics, pharmacy and business. They explained that they like to interact with people and apply their knowledge to real life. In their views both of these factors were lacking in mathematics to a large extent.

The second group of questions was about students' experiences with university mathematics.

First, the three students had very different experiences with learning Pre-calculus. Amanda needed the course to recall her algebra skills. Even after the ten years gap in her practice with math she was able to get back on track and received a solid B. Contrarily, Brenda and Cindy were not motivated enough to do practice exercises and did not do well. In Cindy's case she even had to repeat the course because she failed in the first run.

None of the three students was planning to continue mathematics in the future. They all needed only one more math course for their programs of study. Amanda mentioned that she would take more courses in mathematics but there was a time issue in her case. The other two students did not seem to be interested in taking more math courses at all. All three of them think that Calculus is somewhat interesting, but they hardly connect the material they study in Calculus to their interests and programs of study. Cindy did not even find a connection between material studied in pre-calculus and her current math course.

Amanda believed that math may somehow help her in the study of other subjects, but Brenda and Cindy wanted "to pass and get out" and "to clean their mind after the final exam". All three students had a goal to get a good mark that would enable

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them to be accepted in the programs of their choice, which are competitive.

The third set of questions was about students' experiences with on-line tutoring technology.

All three students used hand held calculators when they studied mathematics in high school and currently use computers to some extent, but they did not seem to be very technologically oriented. Cindy even admitted that she is "old fashioned in this sense" and that she would rather not use technology for her study in math. Only Brenda had prior experience with on-line tutoring software in her Physics course, which she did not enjoy due to lack of availability of on-line resources in case she needed assistance.

Amanda's experience with the on-line software for the Calculus course differed radically from Brenda's and Cindy's. This is where her previous experience with mathematics, her attitude in this course, and her ability to study independently played a role. Amanda felt satisfied and optimistic during her work with the software right from the beginning. Brenda and Cindy described their first reaction to the use of the on-line software as irritation, boredom, and helplessness. Both Brenda and Cindy were overwhelmed by the on-line assignments. All three students admitted that the navigation was easy and straightforward, but learning to use the equation editor was a difficult job. Nevertheless, Amanda handled it as a part of the task to be completed in order to communicate her answer to the system, while Brenda and Cindy were unhappy about the need to learn this particular skill. Cindy found this was "the worst aspect" of the software and viewed the job as unnecessary because it was much easier to write the answers on paper. However, she also liked to receive quick feedback from the system. The work habits of the three students differ as well. Amanda liked to review her work and to find mistakes or even re-do the whole problem if her answer was wrong. Brenda preferred to read similar examples and references in ebook if she did not know how to solve a problem or to correct her error. Cindy mentioned that she needed a human explanation so she worked on problems with a tutor and then submitted her answers.

As the students spent more time using the online system, they started to appreciate its usefulness and merits to a larger extent. Both Brenda and Cindy felt more satisfaction with their practice. When Brenda discovered that she had access to on-line resources, she started to practice more often, whenever she had time between lectures. The description of her experience now resembles many similarities with Emma's case (Volistedt, 2010) discussed above, such as "being diligent", "remember all steps" and "practicing as much as possible to prepare for important exam". Cindy felt more optimistic as well and saw the value of the tool for her review before tests, but she still was overwhelmed by the length of the assignments and would have preferred to complete the work in smaller chunks. Amanda continued to enjoy using the on-line system and she admitted that the extra practice helped her to build a confidence in her performance. While she thought that she would probably understand the material of the course even without the on-line tool, she confirmed that it was also good for review and for getting organized. Amanda stated that she would do the exercises even if no mark was assigned to them. A similar claim was made by Brenda with respect to her Biology course when she attributed her action of doing an on-line quiz for no mark to her interest in the subject. When talking about Calculus on-line assignments, both Brenda and Cindy proclaimed that it would be hard for them to be motivated to do the quizzes just for practice and that 10% of total mark would be a more adequate weight for this task than current 5%. Finally, all three students recommended keeping the on-line component for the future delivery of the course.

It is informative to juxtapose the three students' interviews with the statistics from whole class. The findings are as follows:

Only 13% of the students used the on-line practice regularly, 26% used it for review before the tests, 55% postponed solving the on-line problems till the end of the course, and 8% did not use the on-line system at all (some students gave more than one answer).

The majority of students (70%) used the on-line system "just for solving quizzes" and only 30% of the class used the additional on-line resources. (It remains unknown whether the students were not aware of the option to use the resources or they simply ignored it.)

By the end of the course 53% of the class felt either satisfied or optimistic when using the on-line system, while 46% reported being irritated. About 30% of students were amused, surprised or exited about working with on-line system. Another 30% felt suffering, boredom, or helplessness. (Some students indicated that they experienced both positive and negative feeling regarding the on-line system at the same time.)

Forty five percent of students reported a change in their attitude after more practice on-line.

The majority claimed that navigation was easy (80%), but typing of formulas was not (62%).

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The majority found that on-line practice helped them to review for tests (84%), to understand material better (72%) and helped to improve their mark (55%). At the same time 38% of class considered the on-line quizzes as being an unnecessary extra work.

The majority of students (64%) were in favour of continuing the use of the on-line system in Calculus. The remaining 36% recommend not using it in the future.

4 Conclusion

The experiences collected form the three students are not meant to be generalized in any particular sense as they belong to only 13% of the class population of the students who worked with the on-line assignments regularly throughout the semester. Even data from the whole class would characterize only this particular group of students and might differ from other classes in another semester. Nevertheless, the data are informative in many ways. If we try to classify the three students according to the types identified by the instructors [13], then Amanda most likely belongs to the "Top" group, since "she can work independently", Brenda -- to the second group of "OK students" because "she can reproduce work shown to her", and Cindy is closer to the third group of "Border-line students" since she "does not really make connections between topics". This was also reflected in their final results: Amanda received an A, Brenda a low C and Cindy a D.

In terms of assigning personal meaning to the on-line activity, we observed that Amanda did see the value of practice from the beginning, while Brenda and Cindy acquired meaning gradually as they more and more became engaged in the activity. Students like Brenda and Cindy require external motivation in the form of the weight of the assignment in total mark and frequency of deadlines. It is critical for these students to start doing the on-line practice regularly in order to develop the habit of "working hard" and "practicing as much as possible". Regular on-line practice changes the local culture of learning and helps the students to assign personal meaning to this activity. This is where the instructor's decision about the specific way of using the software can make a difference.

Instructors can and must participate in developing learning micro-cultures in the course, particularly by choosing to use the on-line tutoring component. From the interview and surveys I learned that many students changed their personal meaning of this on-line practicing activity as they proceed by doing more problems and reflecting on their own mistakes. Similar to Emma's case they found that the initial level of anxiety decreased with more practice and that successful performance helped to build optimism and confidence. It is important however to keep in mind the following aspects:

- Majority of students needed an extrinsic motivation for starting these on-line assignments. Thus one must carefully plan for the weight assigned to this activity, the frequency of deadlines and the amount of work assigned.
- Many students did not realize that learning materials (ebook, video, sample solutions) are placed on-line along with the assigned problems. Students must be familiarized with and constantly reminded of the on-line resources available to support their self-study.
- Many students were unhappy about not receiving partial credit for their on-line work which is marked based solely on wrong or right answers. A better way to assess students' progress would be a combination of written and on-line assignments, and instructors should use it where possible. On the other hand, students must be able to review and correct their solutions until their answers are accepted by the on-line system.
- Students must be educated on how to take responsibility for their work and how to decide on the amount of extra practice necessary for their educational goals.

There are two further issues which became apparent from students' responses and need to be considered. One is the ability of students to "work smart", that is, to reflect on the results of their work, to check their solutions, and to use the online tutoring system as a partner for learning certain methods along with their conceptual layout. Many students unfortunately lack this ability to a large extent. Either they don't really understand how to study mathematics successfully or they suffer from inefficient study habits (even if they spend hours studying). Developing in students the ability to study mathematics may require a careful choice of problems and a coordination of the material presented in lectures with the homework assignments. Students often prefer having examples to learning general principles. These principles must be presented at the right time so that students would find them useful for checking their solutions and correcting errors in the online assignments. In addition, students should be constantly reminded

that: they can't learn mathematics by simply watching the instructor doing it; they need to understand principles and concepts and not just memorize the procedure; they need to accumulate knowledge over years and make connections to previously studied material.

Another big issue is that many students do not relate the material they have to learn in Calculus to their broader programs of study. Many view mathematics courses as obstacles which they have to "jump over" on the way to their career. Even though many students find something interesting in Calculus, they still view it as largely irrelevant and disconnected from what they perceive as "their main area of interests". How can instructors produce a motivation for learning calculus based on students' own interest? How can the lectures help students to make sense of calculus in terms of the area of their studies and make calculus more "applicable to their life"? This problem can hardly be resolved by the use of an on-line tutoring system. In order to address it, instructors of mathematics may consider the use of educational technologies that help students to explore, conjecture and reason mathematically in a combination with learning of basic facts and exercising application of rules supported by on-line tutorials.

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