SITUATED COGNITION AND STUDENTS' CONCEPTUAL UNDERSTANDING OF ELEMENTARY CALCULUS

Victor Kofi Amoah

Alperton Community School, Wembley

According to the situation cognition perspective, knowledge and thinking are inextricably intertwined with the physical and social situations in which it occurs. The implication is that learning situations should be embedded in authentic problem situations that have meaning for the students. This study investigates the effects of two teaching approaches (or strategies) on students' conceptual understanding of differential calculus. These approaches were the Unify Model and Situated Cognition Approach.

BACKGROUND

The value of skill-based calculus courses has also come under fire because computers and calculators now perform most of the manipulative procedures taught in such courses. Hughes-Hallet (1994) points out that what has become inescapable is the impact computers and calculators are having on what we teach: computers and calculators can now easily compute definite integrals, sketch graphs, solve equations, and find high powers of matrices and are able to do the algebraic manipulations that have been the backbone of high school mathematics for decades. Serious questions are now being raised about the kind of mathematics that should be taught. The general tendency is for less emphasis on skills and greater emphasis on underlying concepts. According to Ostebee and Zorn (1997), whether one views calculus as an introduction to pure mathematics or as a foundation for applications (or both), the conclusion is the same-concepts, not techniques, are truly fundamental to the course.

Although academics who argue for calculus reform, having studied mathematics rather than educational theory, do not use the terminology of situated learning (situated cognition), some of the ideas of situated learning are evident in their work. Both situated cognition and calculus reform use cooperative and participative teaching methods as the means of acquiring knowledge. They both place the learner in the centre of an instructional process. Both calculus reform and situated cognition emphasize on the use of authentic context that reflect the way knowledge is used in real life.

The purpose of this study was to apply the theory of situated cognition to design an effective learning environments for mathematics students in a Science Foundation Programme at the University of the North in South Africa and: 1) to investigate students' responses to this environment and 2) to investigate the effect of this instructional design on students' understanding of differential calculus as compared to the Science Foundation Programme's traditional approach to teaching of calculus.

METHOD

Participants

The participants for this study were 97 Science Foundation Programme (also known as University of the North Foundation Year Programme – UNIFY) students of the University of the North in the Northern Province of South Africa in the 2001 academic year. Of the 97 students, 24.5% were females and 75.5% males. The mean age of the participants in the study was 19.7 (S.D. = 1.6).

Procedure

To investigate the effect of the situated cognition instruction on student's conceptual understanding, an experimental design involving an experimental group (E) and two control groups (C1 and C2) was employed. The experimental group was given situated cognition instruction and was taught by the researcher. Group C1 and group C2 were taught the UNIFY teaching approach by two experienced mathematics teachers at the university. A calculus test was then administered to all groups at the end of the course. The primary purpose of the test was to explore the students' conceptual understanding of elementary differential calculus after the calculus course and also to investigate the difference in the performance between students receiving situated cognition instructional approach and those receiving the traditional UNIFY instruction.

Situated Cognition Instructional Approach

The instructions for all the three groups were similar in that the groups were taught with the emphasis on concepts. All the three groups used the same calculus worksheets developed by the Science Foundation Programme. In addition, the researcher developed worksheets to for computer laboratory work. The situated cognition instruction was more technology intensive but in the other group no technology was used. The situated cognition group followed the approach below:

Authentic Activities

Since authentic activities is a critical component of a situated cognition model, attempt was made to place the learning activity in an environment that closely parallels a real world situation, essentially in an authentic context that reflects the way that knowledge will be used in real-life. The students work on real-life projects in groups. They work on projects outside of class in groups of about three, spending two to three days on each project. They also work on some of activities in the computer laboratory and classroom. Authentic context and tasks enabled the students to reflect on the work in a meaningful way.

Use Multiple Representations

Another strategy that was considered in improving students' conceptual understanding of calculus was the use of multiple representations of the derivative concept and students worked in translating from one representation to another. Also, students related the knowledge to physical experience. Translating from one representation to another was expected to increase students' ability to use unfamiliar representations, leading to a richer understanding of the derivative concept. The course emphasized on graphical and numerical approaches throughout. Worksheets were developed to have a multiple representations of derivatives.

Use of Technology

Situated learning support collaborative construction of knowledge. Each investigation (from the worksheets) in the classroom, computer laboratory and outside the classroom were addressed to a group. The computer laboratory was natural settings for cooperative learning. Students benefited from explaining their thought processes to their peers in the laboratory. Conversations between students became a valuable part of the course, whether or not cooperative learning was part of the original course design. The use of the graphing capabilities of the software (mastergrapher) gave students a geometric view of calculus concepts. The graphical software was incorporated in the teaching calculus to help students to make stronger connections between graphical and symbolic representations.

Unify Approach

In UNIFY mathematics teaching approach, no lecturing took place at the beginning of or during any learning activity. The reason being that through lecturing a facilitator is likely to remain ignorant of learners' prior knowledge, and the knowledge that learners construct as lecturing takes place. According to the UNIFY approach, facilitating learning should be about engaging the learners in learning and for that to happen a facilitator should keep track of ideas that learners construct. Teaching was aimed at mathematics sense-making. The teaching involved: 1) continuous identification of students' ideas. In this case, was through students written work and through mathematical discussions that were held in class, 2) continuous exchange of mathematical ideas with oneself, between peers and/with facilitator.

Questionnaire and Classroom Observation

A five point lickert scale questionnaire was administered to evaluate the students' perception of the situated cognition approach. Students have to indicate how they felt about the different components of the calculus course. There were also three different non-participant observers who were in six of the sessions. The students were informed about their presence and why they were observing them. All the observers are qualified and experienced science educators working in the same science foundation programme. The students using the situated cognition approach were asked to indicate to what extent they agree or disagree with the statements about the calculus course.

RESULTS AND DISCUSSIONS

Questionnaire

Overall, all the responses about the group activities were positive, with 82 % of the students saying they enjoyed working in groups to accomplish a task and also, 82 % indicating that they learned a lot from doing group assignments. Seventy-one percent of the students felt each group member contributed to the effectiveness of their presentation, and 86 % indicated that the worksheets provided were good basis for classroom discussion. Seventy-one percent of the students agreed that they accomplished more as a group than could have if they worked individually.

Four of the items concerned with how the use of technology enhanced the students learning. Ninety-three percent of the students agreed that the computer laboratory work was a great help in their understanding of the calculus concept, and 86 % indicating that the computer laboratory work enhanced different representations of the calculus concept. Only 57 % of the students have the view that the computer laboratory work encouraged communication among the classmates. This understandable since each student is provided with a computer and the interaction will be more between the computer and the student. Below are some verbatim comments made by the students about the course.

- The course is very interesting. The thing is you not only listen to a lecture, but you'll do most of the work on your own; which helps you to understand more clearly. You will also develop the skill to do research. In our group we sometimes use technology to explore some of the things.
- It is part of mathematics which deals mostly with graphs to describe life and environment we live in. It is also linked with technology. It makes a person to be creative.
- It helps you to understand things and not to memories them. It helps people to understand the mathematical formulae and how to apply them in a real life situation.

Performance of groups in the pretest

The completion of first semester mathematics course was used as a covariate. Statistical comparison of the mean data of the situated cognition group (E), and the two UNIFY groups (C_1 and C_2) after first semester mathematics indicated that the groups were equivalent on the their mathematics tests before the study. Analysis of variance (ANOVA) yielded no significant mean difference in mathematics attainment among the three groups before the study, ($F_{(2,93)} = 2.45$, $p = 0.0917$).

Performance of groups in the end-of-course test

Analysis of variance yielded a significant mean difference in attainment among the three groups in the first post calculus test ($F_{(2,88)} = 13.01$ $p = 0.000012$). A post hoc Tukey's HSD indicated that the Experimental group (E) outperformed all the other groups, whilst there was no significant difference in attainment between schools C_1 and C_2. The rank order was:

$E > C_1 = C_2$.

Table 1: Situated Cognition (E) and Comparison (C1 and C2) Groups Performance

Item	Test Content	E (n=29) (%)	C1 (n=30) (%)	C2 (n=32) (%)
1a	Finding average rate of change graphically	55.2	46.7	50.0
1b	Estimating the derivative at a point graphically	37.9	13.3	28.1
1c	Explaining meaning of derivative	75.9	53.3	59.4
2	Finding the derivative at a point algebraically	82.8	60.0	43.8
3	Estimating the derivative at a point numerically	58.6	30.0	25.0
4	Applying the derivative to solve a problem	13.8	13.3	15.6
5	Recognize the graph of a function if its derivative is drawn	31.0	0.0	0.0

Table 1 shows that the students in the situated cognition group scored highest in four conceptual questions (items 1b, 1c, 3 and 5). The situated cognition group also scored highest on the algebraic question (item 2). This shows that these students did not suffer any loss of computational skills, which is a fear often voiced by educators who are against the use of technology in the mathematics classroom. The results suggest that perhaps a strong graphical understanding of the concept of the derivative enabled the situated cognition group to develop a more complete concept image of the derivative. The study demonstrates that the use of graphing software for functions and their derivatives (item 5) have the potential for producing a richer understanding than that achieved by analytic study alone.

The results of the study indicate that through authentic activities and graphing software, students' can improve their conceptual understanding of differential calculus. It helped the students to build interconnections between the various forms of representations, thus increasing their understanding. The use of graphing software in calculus instruction facilitated a situated cognition instructional approach. Computer laboratory was a natural setting for cooperative learning. Students also benefited from explaining their thought processes to their peers in the laboratory.

REFERENCES

Hughes-Hallet, D. (1994). Changing in the Teaching of Undergraduate Mathematics: The Role of Technology. In *Proceedings of the International Congress of Mathematicians*, Zurich, Switzerland.

Ostebee, A. and Zorn, P. (1997). *Calculus from graphical, numerical, and symbolical points of view*. Harcourt Brace College Publishers. Orlando, Florida.