Hans-Georg Weigand, University of Würzburg (Germany)

NEW WAYS OF COMMUNICATING IN MATHEMATICS TEACHER EDUCATION: LINKING TO THE INTERNET[1]

Abstract:

New technologies are rapidly changing our ways of communication, and also the art of teaching, as well as extending ways of learning. Communication is an essential part of mathematics education and mathematics teacher education. Communications through technology can support the goals of mathematics education courses and programmes, and can promote the professional development of participating teachers and educators. This paper is about a semester-long course "Computers in Mathematics Education" for 150 student teachers which was given at the University of Giessen in 1999. Every student had to have an email address and access to the Internet. Via the Internet, web-based lecture notes, exercises, an electronic discussion panel and an internal course email communication system were provided. Our main thesis is that new technologies provide opportunities to expand and enhance communication in mathematics teacher education. This communication supports the goals of mathematics teacher education and contributes to the professional development of participating teachers and educators.

1. Internet and Mathematics Education

Student teachers need familiarity with a variety of technologies and an understanding of how technology relates to teaching and learning mathematics. I endorse a view of these new technologies that was proposed by Pea back in 1987 - as cognitive tools that can help us restructure, reorganize and resequence our acting and thinking. From this perspective, new technologies offer opportunities not only to address old purposes, goals and means in new ways but also form new purposes, new goals and new means that have not been imagined or considered before.

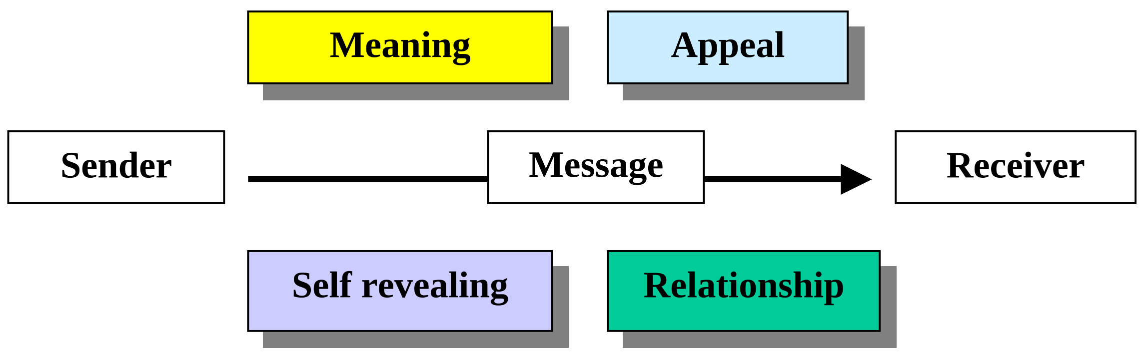
In our discussion of the Internet, different aspects of technology in relation to mathematics teacher education are presented. First, the Internet is a **resource for information**. In addition to the traditional resources of teacher and textbook, students access the World Wide Web to locate readily the information that is available in published books, articles and reports, as well as special electronic publications and web-based instructional materials. Second, the Internet is a **tool for mathematics learning**, an aspect that is growing in importance with the advent of distance learning (Woods 1998). Third, within the classroom itself, the Internet can be used as a **medium for demonstration**, e. g. the use of dynamic visualization software enhances special topical lectures and seminars (http://www.ies.co.jp/math/java/) or visualization of different proofs of the Pythagorean Theorem (http://www.ies.co.jp/math/java/pythagoras.html).
Fourth and finally, the Internet is a **communication tool,** which facilitates student-teacher and student-student communication. I have focused on the Internet in its role as a communication tool

[1] I am especially grateful to Bridget Arvold from the University of Illinois (USA) for giving me the opportunity of joining her Internet-enriched class in the fall term 1998/99 and for our many discussions about the various uses and influences of electronic communication.

and concentrated on the types of interactions it afforded students and teachers on a university campus.

2. What is communication?

The scientific semiotic is about culture as communication, whereby an extreme position holds the opinion that culture *is* communication (Eco 1995, p. 33). Communication refers therefore not only to verbal and written messages, but also to any behaviour of a human being. Watzlawick (1969) developed a system of axioms of communication with the first axiom called: “One cannot not communicate”. It assigns, to each message between a “sender” and a “receiver”, an aspect of meaning and an aspect of relation. This model was extended by Schulz von Thun to a “square model”, which relates an aspect of self revealing and an aspect of appeal to each message (1981, P. 13).



The aspect of self revealing means that the sender gives something of himself, and the aspect of appeal also shows that a purpose is connected with each message.

3. Communication and mathematics education

Communication has gained recognition as a vital element in the learning of mathematics. The theory of constructivism and interactionism especially emphasizes (see Jaworski, 1994) that instruction cannot be understood simply as “information transport” from the teacher to the learner. Rather instruction must be regarded as an extremely complex relationship or communication network between teachers and class, teacher and pupil, pupils among themselves as well as pupils to parents and persons outside the classroom.

The NCTM Standards (1989) in the USA – greatly influenced by the theory of constructivism – declared principles for constructing the curriculum. These are, on the one hand, the content standards like algebra, geometry or statistics and, on the other hand, mathematical connections, mathematics as problem solving and also mathematics as communication.

> “Communication is an essential part of mathematics education. It is the means by which ideas are shared and a vehicle for clarifying understanding.” (p. 85)

4. Literature Review

In recent times, the establishment of learning laboratories and the number of articles related to communications via new technologies have provided evidence of a growing interest in electronic communications. Despite easy access to resources such as classroom activities incorporating Internet use, only a few empirical investigations focus on researching such communication, especially in mathematics and mathematics education.

Among the studies, Swets (1997) reported on using electronic conference software to enhance collaborative work and to get feedback from students about their understanding of mathematical concepts. Findings suggested that electronic communication aided formative assessment and encouraged input from students who were unlikely to participate in traditional communications.
Zack (1995) used email as an effective research tool for data collection to document the improved quality of his course. However he was quick to point out that the success of electronic communication "requires a commitment by the teacher to a spirit of collaboration and interaction and the willingness to adapt to the needs of the students" (p. 206).

A few studies addressed the question of **how** the Internet **influences** mathematics learning and teaching. Gerber and Shuell (1998) observed students while searching the web and emphasized the need for basic mathematical knowledge to undertake a critical analysis of the found data. Liao (1998) performed a meta-analysis to synthesize existing research on comparing the effects of hypermedia and traditional instruction on students' achievement and his studies suggest "positive effects of using hypermedia in instruction" (p. 355). The particular factors that contribute to such improvement remain a mystery. Clark et al. (1998) used the science resources on the World Wide Web in their lectures and found that students encountered new challenges that were associated with a lack of computer literacy and information-gathering skills. Yet they noted that the World Wide Web resources opened "many doors that were previously unavailable in classrooms" (p. 304).

This study focused on technology as a communication tool to promote learning. The study was explorative in nature and contributed to the development of various hypotheses. Its findings highlighted the need for in-depth empirical investigations of particular interactions and practices influenced by Internet-assisted communication.

5. The Internet-based course CiMU

5.1 Goals

The course CiMU ("Computers in Mathematics Education") is obligatory for high school student teachers. It is divided into a two-hour traditional lecture and a two-hour exercise in the computer lab. The fundamental tenet was that the students get to know the computer as an important and helpful tool for solving problems. A perceived outcome was that students would be able to discuss probable effects of the use of the computer on goals, contents and methods of mathematical learning and instruction. The three most important software tools used were a computer algebra system (Derive), a geometrical construction program (Euklid[2]) and a spreadsheet program (Ex-

[2] Euklid is a program similar to Sketchpad. See http://www.mechling.de

cel). Contents of the course were numbers, functions and equations in algebra, and the “dragging principle”, the “modular principle” and the “locus function” in geometry. The most important goals of this course were:

- Getting to know new technologies as modern communication tools.
- Developing central abilities – which are especially important for teachers - such as personal responsibility, working in teams and communication.

5.2 Participants

150 student teachers working with primary and secondary schools took this compulsory “Computers in Mathematics Education” course. Nearly all had a computer and half of the students had Internet access at home. All students had computer access at the university.

5.3 Items of the course

a) Lecture and hypertextscript

The lecture was given in a traditional way, however no blackboard was used and texts were written directly into the computer and projected onto the wall. Thus the “blackboard script” could be put on the web immediately after the course. Additionally, the computer was connected to the Internet so that external Internet resources could be used in class. A hypertext script with extended assertions, weekly exercises for homework and the solutions to these problems were published.

b) Exercises and assistance for the exercises

The students had to solve the exercises weekly. This could be done in a two-hour exercise period in the computer lab during which tutors were present for consultation. The exercises could also be done at home and the students had the opportunity to use email to ask questions at any time. Every week one group of students (a project group, see below) had to submit their solution to the homework exercise to the instructor. The revised solution was published on the web.

c) The program WebCT

From the different systems that support multi-media-based courses, like CyberProf[3], Asymetrix Toolbook[4], Macromedia Authorware[5] or WebCT[6], I chose to use the program WebCT (Web Course Tools). It is an integrated collection of Internet instruction tools for the creation of an online Internet course. It is both an environment for creating electronic courses and also a learning environment for students. WebCT was developed in 1995 at the University of Columbia and was marketed commercially. The system supplies structured assistance in the following ways:

- it helps the instructor put scripts and texts onto the web,

---

[3] See: www.etb.uiuc.edu/cyberprof/music/199T/index.html

[4] See: www.asymetrix.com/products/

[5] See: www.macromedia.com/

[6] See: www.webct.com

- it is a database for the administration of the course participants,
- it assigns an email address to each enrolled student,
- it contains a discussion panel,
- it supports the creation of on-line tests which can be evaluated electronically, and
- it supports students' creation of homepages.

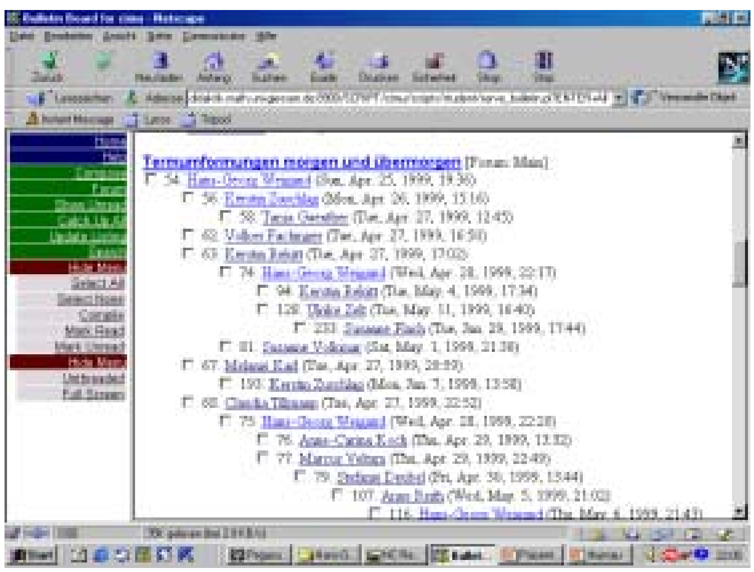
The system is password protected, meaning that only the course participants have access to the electronic classroom.

d) Email Communication

Every student had to have access to a computer with an Internet connection. The email system of WebCT allowed the students to communicate very easily among themselves, within a group of students, and with tutors and the instructor.

e) Discussion Panel

It is nearly impossible to have a discussion in the lecture room with 150 students. The electronic discussion panel is an adequate tool for giving each student the possibility to "have their say". The instructor or the students initiated the discussion topics.



Screenshot of the discussion panel

f) Announcements and Inquiries

The homepage of the course or an email distribution list allowed the teacher to give instructions to all students outside lecture time. WebCT also allowed on-line quizzes over the web which were used for getting information from the students about the problems and difficulties of the course. Participants could not only download scripts and exercises but also files for the computer programs Derive, Euklid and Excel for independent use at home. Electronic inquiries provided feedback on how the students used these programs.

5.4 Student assistants

Six student assistants helped with this course. One administrated the WebCT system (assignment of passwords and email addresses, creation of new directories, …), one created the electronic script and put it on the web while one placed the exercises and their solutions on the web. These three tutoring students or student assistants also supported the participants in all technical questions concerning WebCT and the creation of web pages. Three additional student assistants worked as consultants in the computer lab during exercise time, but they also answered email inquiries throughout the week.

6. Assessment

Typically, students gained credits for the course CiMU by passing a written examination at the end of the semester. Course instructors, focused on developing competencies in communication, need to think about whether traditional assessment procedures are suitable or whether new kinds of assessment should be employed. Referring to the NCTM Standards (1989) and especially to the NCTM Assessment Standards of 1995, the guiding principle is that assessment should evaluate what children can do and not what they cannot do. Assessment is seen much more as a process which accompanies the whole instruction, rather than as a one-off effort.

In CiMU I tried to evaluate a lot of the different efforts produced by the students. They earned credits for five different activities.

1	Participation in the electronic discussion	10%
2	Creating a sample solution of the exercise	10%
3	Doing a special activity in the computer lab	10%
4	Doing a teamwork project	35%
5	Final written examination	35%
	Percentage needed to pass the course	70%

The students had to do individual (nos. 1, 3, 5) and group work (nos. 2, 4) tasks. At the beginning of the semester the students were divided into 15 project groups with, on average, 10 participants per group. Each group had to create a sample solution to one of the exercises and undertake a semester-long project. The project topic was assigned to each group at the beginning of the semester. There were topics like numbers, terms, linear functions, exponential function, equations, triangles, squares, circles, and measurement of surface and volume. Throughout the semester they had to elaborate upon didactical considerations associated with one concept and to create a webpage that helped other student teachers grasp the meaning of that concept and the didactical considerations for mathematics education. The outline of the pages included the following:

1. Mathematical considerations about the concept
2. Relation to the syllabus
3. Concept development
4. Literature
5. Interesting links
6. A special mathematical activity (like an inquiry with pupils, students or teachers)

7. Worklist for all group members.

Development and organization of the project had to be done entirely by the project group. During the lectures I didn't talk about the technical implementation, however a special introduction to the creation of web pages was given outside lecture time. The student assistants were responsible for technical consultation.

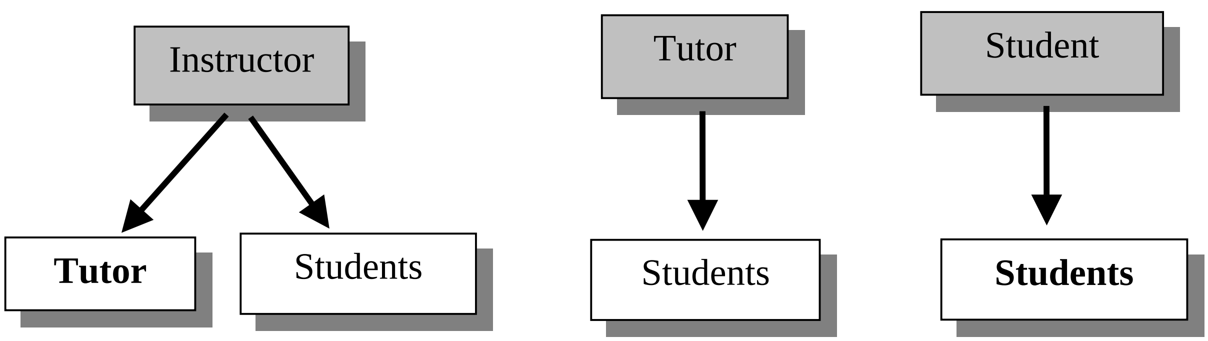
7. Communication in CiMU

In the following sections, technological communication is classified according to the partners involved in the communication process. Three different types of communication are distinguished.[7]

7. 1 Types of Communication

Type A: Announcements

An announcement is a one-way communication from an individual to the entire class for the purpose of providing information to the entire class. There are three subgroups:

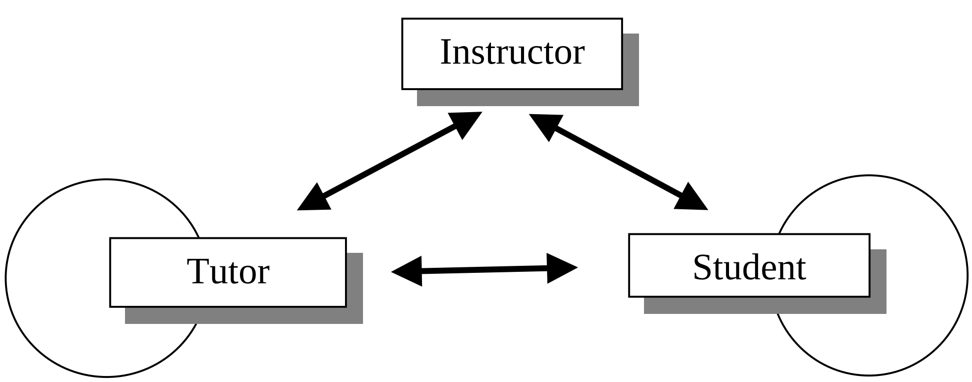


Type B: Discussion

Internet DISCUSSION is the interactive communication that is accessible to either an entire class (whole group) or to a specified subset of a class (small group).

Type C: Dialogue between

There are dialogues between instructor and tutoring students, instructor and students, tutors and students, students and students.



[7] These levels of communication are the result of a long-standing discussion with Bridget Arvold.

Concerning these types of communication our main research questions were:

1) What types of communication are supported by Internet use in mathematics education courses?
2) How do these types of Internet-supported communication influence the actions of mathematics education students and instructors?
3) How do these types of Internet-supported communication affect instructional design?

7.2 Case studies on the types of communication

The following section includes specific examples of each type of communication and the stated or inferred purposes and outcomes related to each.

Type A: Announcements

The instructor used the internal email for explanations of, and supplements to, the lectures:

> *Instructor: "Unfortunately we are not as far ahead as I would have required, therefore I ask you to ..."*

> *Instructor: "Please refer to the new exercise sheet. There is an error in problem 1. Of course the problem is to find the approximation sequence for 'e' and not for 'n'."*

The student assistants used the announcements to obtain timely feedback.

> *Assistant: "Part of my job is to put the solutions of the exercises on the web. Please can you tell me whether you are confident with the representation of the solutions or not."*

There were a lot of other announcements about articles in newspapers and journals. Students took advantage of the opportunity to gather information:

> *Student: "Who can recommend well tested learning software for different school levels? I am especially interested in your experiences."*

There were also critical announcements concerning the lecture and the exercises:

> *Student: "I think the exercise problems cannot be solved with the knowledge introduced in the lectures. I would find it helpful if we got more hints and background knowledge in the lectures."*

> *Student: "In this course computer applications for primary schools and schools for handicapped children are missing."*

Type B: Discussions

The discussions in the whole group developed over time. The lecturer and the students posed questions. Here is a short sequence of one panel discussion:

> *Instructor: "What will be the point of doing term manipulations by paper and pencil in the future? Should it still be taught at school?"*

Student A: "With the computer, complex term manipulations can also be done at secondary school level. The question is however, whether students can reconstruct the computer transformation because it only displays the result and not the step by step procedures."

Student B: "Surely it makes no sense at all to draw hundreds of parabolas by hand if you can do this more easily – and you will do it after leaving school – with a computer. It is enough if you do it for a small number."

Student C: "There is no doubt that the contents of the math lessons will change if you use a computer. But you have to have a basic knowledge to be able to use a computer. The question is, what is basic knowledge?"

Student D: "But students do also learn from errors. The computer makes – normally – no errors and the students don't get the opportunity to learn from errors."

The panel discussion statements showed intuitive responses particularly due to the students' own experience from school or in the field. Students referred not only to recently published newspaper articles but also to journal articles that were not mentioned in the lecture. The panel discussion may be summarised as follows:

- The contributions show parallels to the actual didactical discussions at scientific conferences about the meaning of paper and pencil activities and the changing of the goals while using a computer.
- There was a real discussion by the panel and not only an announcement of single statements.
- The contributions were usually written in essay form. They were quite long – too long and often too tangential for in-class discussions. This shows that electronic discussion has to be learned and that the criteria for an appropriate panel discussion are still open.
- Apart from contributions on an intuitive understanding level there were also statements indicating a good knowledge of the actual literature.
- Many statements referred to the main aspects of the lecture like the modular principle or the possibilities of a dynamic representation of concepts.

Overall, the panel was a good opportunity for getting immediate feedback to the lectures and exercises, for getting to know the opinions of many students especially the typically "quiet" students (self revealing aspect of communication), for learning about the difficulties and misconceptions of students, and for reflecting upon the lectures and considering changes (communication aspect of appeal).

Type C - Dialogues

a) Dialogues between instructor and tutoring students

The organization of the Internet-based course required a precise weekly schedule with all necessary activities i.e. installing and updating WebCT, creating and administering a database with 150 students, and putting scripts, exercises and solutions to the exercises on the web. Three tutoring students were responsible for these technical operations. The communication between the instructor and these tutoring students was – of course - mainly about technical questions. On the other hand, the communication with the tutoring students who were responsible for the support of the students in the computer lab was more about the contents of the lecture.

b) Dialogues between instructor and students

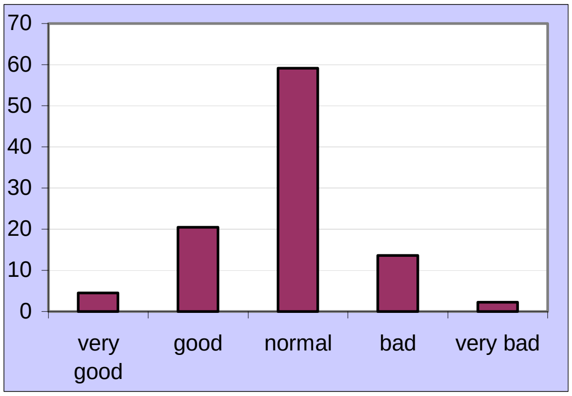
On the one hand the communication was about questions such as difficulties with the exercise problems or criteria for passing the examination. On the other hand the communication was about very personal things like difficulties in studying, problems with other members of the project group and the isolation syndrome. Without electronic communication I surely would not have gained such information. In individual cases the electronic discussion led to a personal meeting. During this course I learned to care more about the social aspects of students.

c) Dialogues between tutoring students and participants

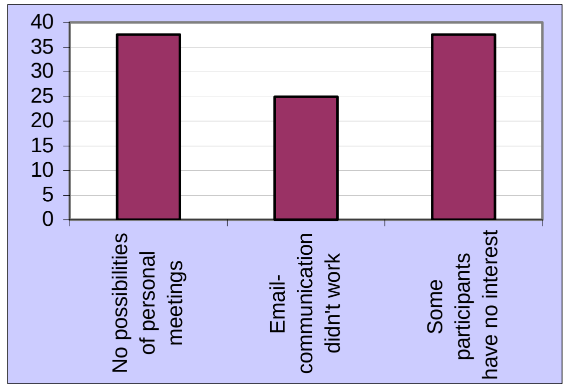
There were only a few student questions directed to the tutoring students. Each tutoring student received – on average – only 1.5 emails a week. The reason for this disappointing exchange was certainly not that the students had no difficulties with the exercises, because difficulties were apparent in the final test. It may be due to several factors e.g. that the students preferred the exercise hours in the computer lab – sometimes nearly 50% of the students took part in these hours, that students concentrated on the time-consuming project work, and finally, that students perceived that questions about the understanding of concepts could not be adequately answered through email. Concerning the last point, the reactions of the students show the limitations of electronic communication and raise the question of whether new tools are necessary for transferring these ideas over the web, e. g. electronic panels which include text and hand-written graphics (see Hoppe 1999). Finally the well-known fact that additional resources are of more interest to good students than weaker students is supported in this study.

d) Dialogues between students

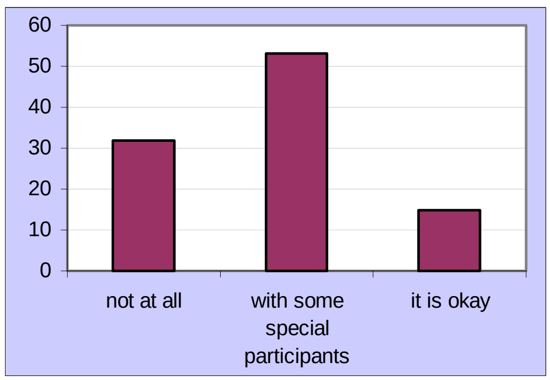
Information about this type of communication was only received in an indirect way when students themselves reported on their communications. Some electronic inquiries were constructed to get to know more about the communication within a project group. The following inquiry was undertaken in the middle of the semester. The vertical bars represent the percentage values.



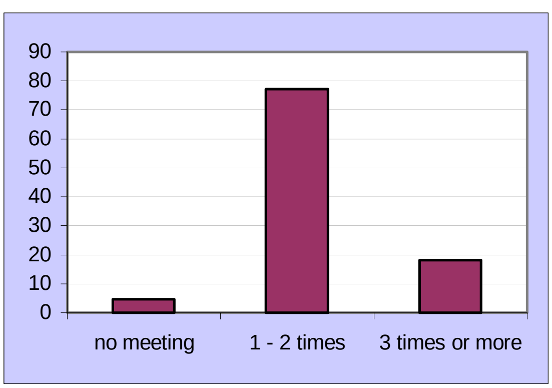
How did the co-operation in the group work?



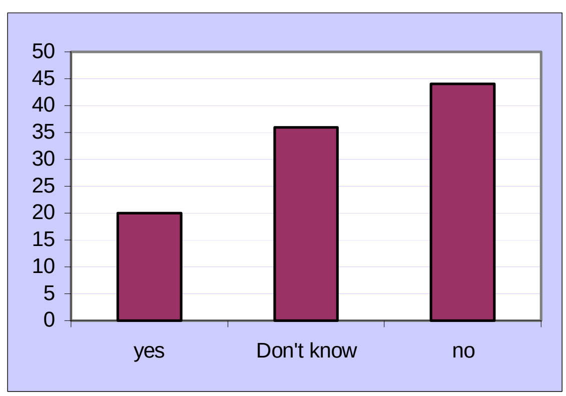
What do you think are the reasons for the group not co-operating fully?



Does email communication work in your group?



How often did you meet apart from lecture time?



Do you think some group members do not engage fully with the work?

These diagrams suggest that the difficulties of co-operation lie not in the electronic communication but in the lack of opportunity for personal meetings and in the lack of interest of some individual group members. An email inquiry directed toward those project groups which complained about problems and which could not meet the project deadline confirmed these difficulties and resulted in further points of criticism:

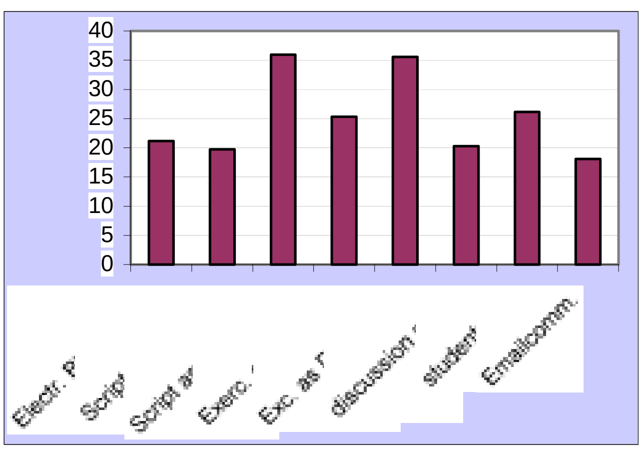
- Time-consuming work and relatively new work like creating web pages was categorically rejected by some team members.
- The quality of the individual contributions was worse (bad spelling, no table of contents or references...).
- The number of students per group (with up to 10 students) was too large.
- Finding time for a meeting outside lecture time was difficult.

However the students also noted positive aspects of the project work:

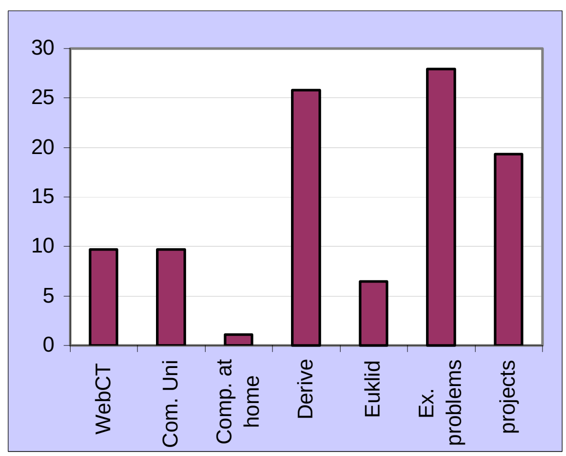
- The project topic gave scope for personal ideas.
- Thinking about a special concept in more detail was good preparation for work in school.
- There was an (electronic) product at the end of the work, which made some groups very proud.
- There were a lot of debates about mathematical contents within the group.
- The groups whose members already knew each other quite well worked well together.

8. Difficulties of the course and the final test

An inquiry at the end of the semester shows how the students evaluated the different items of the course.

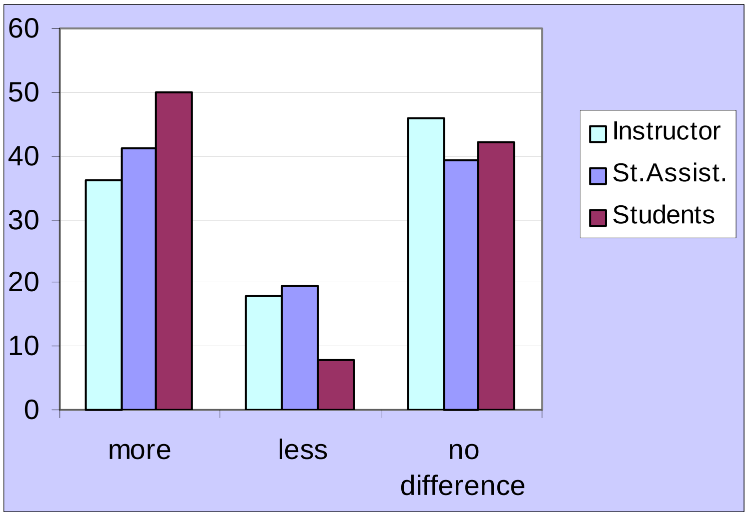


CiMU offered different items. What was most important for you? Enter 1 for “most important”, then comes 2, then 3, then 4...



What caused you the greatest difficulties?

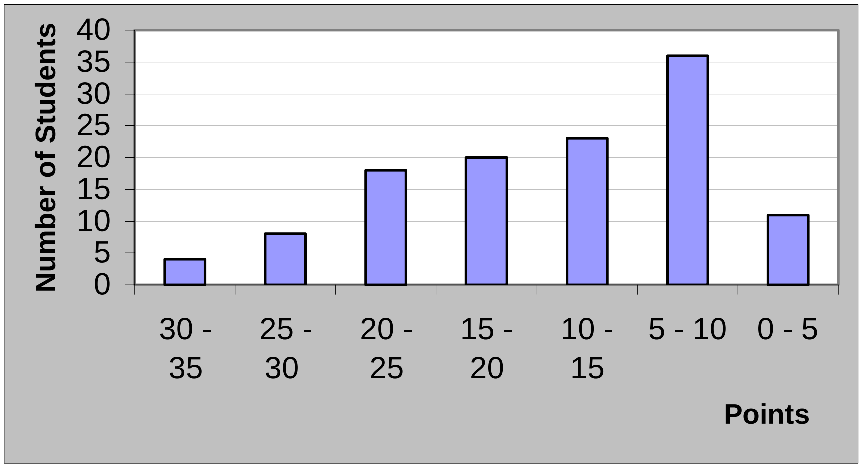
The diagrams show the dominant aspect of the paper material. The difficulties were obviously at the course content level (exercises, project work) and not at the technical level of handling the computer or the program WebCT (except perhaps the handling of Derive).
At the end of the course the students were asked whether or not they had communicated more, or less, in this Internet-based lecture course than in traditional courses. The following diagram shows the percentage of students who answered the question below it.



Communication is the verbal or written exchange of ideas with others. Do you think that you communicated more or less in this course – with the instructor, with the student assistants and with your fellow students - compared with a traditional course?

The diagram shows the classification into two main groups of students: one group which grasped the new opportunities and the other which did not (the students who answered “no difference”). This classification into two groups was shown within all activities of this course i.e. participation in the discussion panel, email discussions and the project work. The good student (according to the results of the final test) embraced a wider range of activities than the other students.

The final test was taken by all students of the course at the same time in several computer labs at the university. Here are the results



The results are not as good as in the traditional courses taken in previous years. The Internet-based communication did not contribute to better results in the written examination. To see the positive effects of the course, it is necessary to look beyond the experiences tested by the final examination and to note the development of teamwork and communication skills. This was the first time most of the students had engaged in group work and hence they had become acquainted with the type of problems inherent in this method of working. If communication is seen a crucial aspect which contributes to the professional development of teacher education then the students have moved a step in this direction. However they would be deemed to have failed if only the results of the final test were considered.

9. Summary and conclusion

The students did not have significant difficulties in using the Internet as a communication tool, however only about a third to a half of the students regularly spent time on local independent electronic communication.

- The communication type A (announcements) was used frequently by the lecturer and the tutoring students but the participants of the course used it infrequently.
- The panel discussion (type B) was quite popular with all students. Sometimes the discussions were a catalyst for discussions in the lecture and it was a pity that continuing these debates was nearly impossible during a lecture with such a large number of students. The panel discussion may play a more important role for seminars and lectures with fewer students.
- The dialogues between the lecturer and both the tutoring students and the students themselves (type C) can be improved. Perhaps it requires new ideas and possibly new electronic tools and new lecture methods to give more importance to this type of communication.
- Suggestions for instructors of similar Internet-based courses include the following:
  - The lectures need to include time for addressing technical questions.
  - The project work needs to be less time consuming if final test results are to be improved.

  - The evaluation of the project work needs to be less problematic. Giving all members the same credit is not always appropriate.
  - An increased use of worksheets to prepare students for the lectures would be beneficial.
- If you see self-instruction as an important component of a course, the experience of this lecture course showed that the Internet is ONE tool which can stimulate students to take steps in this direction.

References:

ARVOLD, B, WEIGAND, H.-G., Communication-Assisted Mathematics Teacher Education via the Internet, to appear 2001

CLARK, K., a. o., Integrating Mathematics, Science, and Language Arts Instruction Using The World Wide Web, Journal of Computers in Mathematics and Science Teaching (1998), 17 (4), 295 - 309

CLARK, K., a. o., Integrating Mathematics, Science, and Language Arts Instruction Using The World Wide Web, Journal of Computers in Mathematics and Science Teaching (1998), 17 (4), 295 - 309

ECO, U., Einführung in die Semiotik, München 1994

GERBER, S., SHUELL, TH., Using the Internet to Learn Mathematics, Journal of Computers in Mathematics and Science Teaching (1998), 17 (2/3), 113 - 132

HOPPE, H. U., LUTHER, W., OTTE, W., TEWISSEN, F. (Multimedia-gestützte Vorlesungen in einem interaktiven elektronischen Hörsaal - Ansätze und Erfahrungen - in: Schwill, A. (Hrsg.): Informatik und Schule - Fachspezifische und fachübergreifende didaktische Konzepte, Berlin u. a. 1999, 72 - 85

JAWORSKI, B., Investigating Mathematics Teaching - A Constructivist Enquiry, London, Washington D.C., 1994

LIAO, Y.-K. C., Effects of Hypermedia Versus Traditional Instruction on Students' Achievement: A Meta-Analysis, Journal of Research on Computing in Education, 31 (1998), 4, 341 - 359

National Council of Teachers of Mathematics. (1989). *Curriculum and Evaluation Standards for School Mathematics.* Reston,.(http://www.nctm.org).

PEA, R., Cognitive Technologies for Mathematics Education, in: Schoenfeld, A., Cognitive Science and Mathematics Education, Hillsdale a. London 1987

ROCK, D., Communication in Mathematics: Why it is needed - Why it is hard?: Proceedings of the ICTCM 11 in New Orleans, 1998, http://archives.math.utk.edu/ICTCM

SCHULZ VON THUN, F., Miteinander Reden 1, Störungen und Klärungen, Rowohlt, Hamburg 1981

SWETS, J., LET'S TALK: Using Conference Software in Mathematics Courses, ICTCM 10, Proceedings of the ICTCM 10 in Chicago, 1997, http://archives.math.utk.edu/ICTCM/abs/10-C46.html, 11 pages

WATZLAWICK, P., BEAVIN, J. A., JACKSON, D. D., Menschliche Kommunikation, Verlag Hans Huber, Bern u. a. 1969

WOODS, D., User-active Methods of On-line Distance Education, Proceedings of the ICTCM 11 in New Orleans, 1998, http://archives.math.utk.edu/ICTCM/

ZACK, M. H. (1995), Using electronic messaging to improve the quality of instruction, Journal of Education for Business, 70 (1995), 202 - 206

Prof. Dr. Hans-Georg Weigand
Lehrstuhl für Didaktik der Mathematik
Universität Würzburg
Am Hubland
97074 Würzburg
E-mail: weigand@mathematik.uni-wuerzburg.de