Dr. Ewald Bichler

EXPLORATIVE STUDY

CONCERNING THE LONG-TERM-USE OF CAS-HANDHELDS

IN MATH CLASSROOM

The M^3 pilot project, initiated by the Bavarian State Ministry for Education and Culture, forms the context for this research study. The long-term project constitutes an authentic development environment. Therefore the observations from the study can easily be generalized to what is actually happening in the classroom.

The following research question resulted from the concerns of the ministry and from prior research on the use of handheld devices. "What are the effects of long-term handheld use in a realistic research field and what factors influence these effects?" This research question is divided into several sub-questions and each has been investigated using quantitative and qualitative methods.

The results are summarised here arranged under these sub-questions.

RESULTS FOR PUPILS

GAIN IN WRITTEN AND NUMERICAL ABILITIES

With regard to vital written skills, no significant differences can be observed between pupils who are taught with a handheld and those who work without handhelds. However, there are indications that while pupils in handheld classes had lower written abilities when solving equations with tasks where they had to argue a case and substantiate it, they tended to do better, than pupils from classes without handhelds. These observations remained the same throughout the project. These findings are consistent with other studies.

The argument that using a handheld leads to a reduction in numerical abilities was not supported by this project. This is particularly significant because within the scope of M^3 there was no special lesson scheme to improve these skills (as was perhaps the case with the previous

CAliMERO[1] research project, where special task units were established without using handhelds). In the course of the current M^3 project the majority of teachers came to believe that such elementary skills as, for example, converting terms or creating derivations could be gained without them having to be tested in examination tasks without a handheld. Thus the availability of handhelds, which carry out such elementary skills at the touch of a button, raises questions about the importance of testing such elementary knowledge and skills.

RESULTS FOR DIFFERENT ABILITY GROUPS

Different patterns of learning gains appeared in the lower, average and high ability groups of students.

In the first two years of the project it appeared that lower-ability[2] pupils in the pilot classes achieved a higher level of performance than lower ability pupils in the control classes. This result is consistent with prior research such as the CAliMERO project, as well as other research projects[3]. In the CAliMERO project, significant increases actually occurred. However, these increases were not apparent in the third and fourth year of the M^3 project. This may be because of differences in fidelity of implementation: in previous studies, teachers taught with special techniques whereas in the current study teachers integrated the handheld into their individually designed lessons and "only" received offers of materials and further training.

With the average ability groups there were no differences between the control groups and in the M^3 project group.

On the other hand, in the high ability groups in year 10 there was a slight increase in performance compared with the corresponding groups in the control classes. This was no longer evident in year 11.

Thus, the observations show the potential of improvement for the low and high ability students. But the data do not show that lower ability pupils in particular benefit from handhelds, when handhelds are used for a long time. It also is evident, however, that handheld use does not lead to an opening up of the performance gap as was often feared.

‚This result suggests the development of materials for internal differentiation of the different ability groups, as in the current MABIKOM[4] project, is an important step toward helping pupils of every ability level.

[1] Ingelmann, Evaluation eines Unterrichtskonzeptes für einen CAS-gestützten Mathematikunterricht in der Sekundarstufe 1, Berlin: Logos, 2009

[2] A pupil is considered "of low ability" if his total results in the preliminary test at the beginning of the school year are in the bottom quartile.

[3] see, for example (Hong et al., Supercalculators and University Entrance Calculus examinations, Mathematics Education Research Journal, Vol. 12(3), p. 321-336, 2000

[4] The MABIKOM project (Internally differentiating mathematical skill development in new technology-based mathematics lessons) was launched in 2008 and will continue until 2012.

Use and success

The handheld tests gave the first insight into how handhelds were used to solve problems. In these tests pupils in the pilot classes worked on problems on two dates in the school year, used the handheld at their discretion and recorded this in an additional questionnaire. It was apparent that the pupils took a relatively long time (about one school year) to become so familiar with the handheld as an aid that they used it increasingly and appropriately when solving problems. It is interesting here to note that right at the end of the school year those pupils who had used handhelds to solve problems did significantly better than those who did not use handhelds. It was also apparent that the teaching they had (i.e. the teacher effect) had more influence on the way they used handhelds when solving problems than the ability group the pupils belonged to.

When handhelds are used and solution strategies

Most Pupils who used handhelds when solving problems did so toward the end of the school year and typically the handheld use was during the whole solution process. This shows again that it takes a relatively long time for the handheld to be integrated into the individual pupil's problem solving strategy.

At first pupils in all classes used similar solution strategies.[5] It was not until the end of the school year that the solution strategies were more widely varied, both across the whole group and also within individual classes. It was also apparent that teachers had to show the pupils a wide range of different solution methods during lessons. Finally, in interviews with the pupils, it became clear that the written documentation of the solution strategy was also very important. If this documentation is not provided frequently enough in lessons it can lead to the pupils not using handhelds for fear that they will have credit deducted in assessed tasks. Once the pupils are confident with them, then the use of handhelds results in significantly better results in problem solving. Here there are clear indications of a link between the teaching and the use of handhelds in the test tasks.

Multiple Representations (graphical, numerical, symbols)

If solution strategies are differentiated by symbols, numbers and graphs, it is apparent that the numerical area plays a subordinate role. If teachers were asked before a class test how they thought the pupils would use handhelds, it turned out that the pupils with handhelds worked far more with symbols and far less with graphs than the teachers thought.

Recommendations for future research

The use of handhelds when solving problems requires further research on the following questions:

[5] This includes first of all strategies that use symbolic, graphical or numerical methods. Within these methods there are other differences: for example, can the zeros in a function be specified on a handheld by using the command to solve equations and also by using a special command to determine zeros.

- Why is there a difference between pupils working with symbols and graphs and the teachers' expectations?
- What importance does the numerical area have in lessons?
- How can the time it takes for pupils to integrate handhelds more into their personal solution strategies be reduced?
- How important are many different solution strategies in lessons and in examinations?
- How can the skills for working independently with different solutions strategies to solve problems properly be taught in class?
- How can these problem solving skills be documented in writing? How can they be evaluated suitably by the teachers?

THE ROLES OF THE HANDHELD: INTEGRATING INTO THE THREE COLUMN MODEL

The three roles of the handheld as a calculating, teaching and learning tool, as it has been represented in the three column model, is apparent when it is actually used in lessons in the classroom. It is interesting that pupils regard handhelds much more as a learning tool than as a calculating tool. Here it is particularly significant that all the pupils interviewed say this regardless of the lesson in which they participated. This is an indication that pupils regard and accept the handheld as a learning tool.

This benefit occurs largely regardless of the type of teaching. It is clearly triggered by the use of the handheld itself. In classes where the teachers did not integrate handhelds much in lessons, pupils saw them almost exclusively as a learning tool. Information on the use of the handheld as a teaching tool was obviously only very rarely found here. Interestingly, overall pupils said very little about using the handheld as a calculation tool. Therefore they do not see the primary benefit of a handheld as making a large number of calculations. They see the benefits in displaying, checking and supporting learning.

PUPILS' ATTITUDES TOWARD HANDHELDS

Pupils' attitudes to handhelds were generally positive. A clear majority found lessons with handhelds varied and fully half the pupils found them interesting. These values were confirmed in the long term over four years. A clear polarisation was observed in the initial years between one group that accepted handhelds and wanted to continue working with them and another group that rejected them. However, this polarization could not be confirmed in the same way in the long term. These results are important because of their generality: the pupils surveyed had different lessons with different general conditions for learning. The teachers each integrated the handheld into their own personal teaching style, in their own way. The curriculum materials and degree of support available could have an influence but would have to be investigated in more depth for detailed conclusions.

If we look at the development of pupils' attitudes over four years, there was a clear increase in the statements that lessons with handhelds were fun, that the handheld made the work easier, that they would like to continue working with them and would recommend to their classmates that they should go into classes that worked with handhelds. On the other hand, working with handhelds outside lessons went down, which probably indicated a "normalisation" in the sense that the handheld has become a tool that was taken for granted (just like the scientific calculator).

RESULTS FOR TEACHERS

THE HANDHELD AS A CATALYST FOR "MODERN" STYLES OF TEACHING

An evaluation of the lesson logs in the first two phases of the study showed that handhelds are used predominantly in "modern" styles of teaching such as partner, group or project work. This was confirmed in the questionnaires in the later phases of the pilot project. But teaching styles vary in different classes. From this it may be supposed that handhelds could be a catalyst for such types of lessons. Future research will throw more light on this question.

TYPES OF EXAMINATIONS WITH WHICH HANDHELDS ARE USED

Handhelds were allowed by most teachers in written examinations but use varied by type of examination. Sometimes there were whole examinations where handhelds were not used and sometimes individual tasks of examinations were done without handhelds. About half of teachers used handhelds in oral examinations. But only two teachers gave more precise information on the type of oral examinations. These were presentations or assessed project work.

CHANGES IN EXAMINATION TASKS

Teachers did not excessively change their examination tasks (related to written tasks in class work). Inspection of examination tasks shows that after setting the tasks there were no great changes because of handhelds: They would have set most of the tasks even if they had not had any handhelds available. But it can be noted that a wider range of solution strategies enabled by handhelds, such as numerical approximations or graphical work, is reflected in many tasks. Thus, the changes in the examination content are reflected rather in the range of possible strategies used to solve the problems and not so much in the problems themselves.

The project also showed that it is unnecessary to ban the use of handhelds in written examinations. Initially some teachers did examination work in two parts, one part without handhelds and one part with. In this way elementary written skills could be assured. But, as already shown in 0, during the rest of the project teachers predominantly dispensed with an external division of tasks. Note, however, that should the administration forbid this (so as not to

have to make up new legal framework conditions) or if teachers forbid this (perhaps so as to remain consistent what has been familiar up till now), this could lead to an acceptance problem and the ousting of handhelds from the classroom as observed in the pilot project.

TEACHERS' ATTITUDES TOWARD HANDHELDS

A majority of teachers consider the use of handhelds as a good thing.

Should acceptance problems occur with teachers introduced to handhelds, the problems also are likely with their pupils.

Teachers are in two different camps regarding the frequency with which handhelds should be used. One group uses handhelds very frequently (predominantly every lesson or every other lesson) whereas the other group uses handhelds less often than once a week. By contrast, this division is not reflected in pupils. It therefore appears that there is no connection between teachers and pupils on this point. Separate research must be carried out to find out why this is so.

These two camps also were evident in the integration of handhelds into teachers' personal teaching style. With one group of teachers the handheld became a fixed part of their teaching and with the other group it didn't. If handhelds are only used on specific occasions, i.e. perhaps only in a specific lesson in the week or only within a certain period of time (perhaps project weeks), it is difficult to integrate them into lessons.

To summarize, all teachers see handhelds as a tool for teaching and learning mathematics and they all would like to continue working with them. Teachers do not see that there is any danger of losing written skills because n lessons can be specifically designed to prevent this. In future research, the question will be posed of how to ensure that the advantages that teachers generally see will lead to the proper use of handhelds and a more widespread distribution of them.

EFFECTS ON CONTENT

The content appropriate to handhelds is specified in the curriculum throughout all years of secondary school. Handhelds can therefore be integrated into lessons in the long term across all levels of the curriculum.

With the introduction of handhelds, content focus shifted so that a higher number of problems were covered or more complex problems were covered. According to the teachers, some of these more complex tasks were made possible only by the handheld. These include, for example, tasks with a greater range of applications with realistic data, and tasks which deal with interdisciplinary topics or tasks which permit new (and more varied) solution strategies. The shift in focus was not only restricted to problems but also occurred in teaching strategy. Thus, for example, recursive sequences were used in the introduction of the exponential function.

Interestingly, the teachers who shifted the focus of their content in this way also indicated that, as a result, a change in computation procedure occurred. This is another indicator of the fact that the handheld can be seen as a catalyst for "modern" styles of teaching.

EFFECTS OF ADMINISTRATIVE POLICIES

In the discussions with teachers at accompanying project meetings, it became obvious that clearly defined administrative framework conditions are necessary in order to successfully integrate handhelds into lessons. In particular, legal issues and also questions relating to how long handhelds should be used, mainly in relation to their use in central final examinations, must be clarified. These framework conditions must be available in a timely fashion.

EFFECTS OF SUPPORTING ACTIONS

INFLUENCE OF HEAD TEACHERS

During the pilot project school heads did not provide any opposition to the teachers or the project. But it was also the case that most school heads only tolerated the project but did not actively promote it. As a result, on more than one occasion teachers who were scheduled to take part in the project were not assigned an appropriate year group. It was also noted that teachers were sometimes not allowed the relevant time off, making it difficult for teachers to take part in project meetings. In general, this could be expected to reduce these teachers' motivation.

CO-OPERATION OF TEACHERS

If a teacher uses a handheld but remains an "isolated phenomenon" in the respective school, this may lead to the use of handhelds in the school not being established. Therefore, the aim must be the co-operation of colleagues.

In the pilot project it was noted that the use of handhelds in a school can decline so much that the school no longer takes an active part in the project. It was noted in all pilot schools that involving as many colleagues a in the school s possible in handheld use is an important strategy for establishing handhelds.

CURRICULUM MATERIALS USING HANDHELDS

In the long term, separate supporting material is required to integrate handhelds into lessons. Experience from monitoring the project and the results of surveys have shown that curriculum materials required for using handhelds the mathematical and teaching content cannot be completely separated from the machine. Sample lessons with handhelds can, of course, be described in general terms regardless of the particular handheld used. But this is not sufficient for teachers who are only just starting to teach with handhelds because operating instructions are missing. On the other hand it is also the case that materials that focus primarily on the

handhelds' controls are not considered useful by teachers, because the link to content and methods is missing with such materials. However, it is also the case that materials that require very complex manipulation of the handheld are also not suitable for integration into routine lessons intended for newcomers, though they may be suitable for teachers who have advanced handheld skills. In reaction to this discovery, which resulted from discussions at project meetings and questionnaires, a curriculum material format[6] was developed in the pilot project. It is based on smaller examples with method notes that are supplemented with screen videos that can be controlled individually by the user, which first emphasises the intentions of the teaching method and focuses second on the specific operation. Apart from such materials, the subject of using handhelds in examinations and - associated with this - dealing with the question of documenting a solution method, has also proven to be significant for support of teachers.

DOCUMENTATION OF SOLUTIONS

If a teacher does not have any experience of teaching with handhelds, great problem areas are how to operate the device and the question of using them in examinations. These must be dealt with appropriately with materials and/or further training. In the M^3 project, by providing pupils with materials and further training, a trend was detected that difficulties with operating the device and with documenting solutions could be overcome successfully. But this did not happen to the required extent. Further research should deal with the question of how the documentation of solutions can be improved

OUTLOOK

As shown previously, in the field research context of the M^3 pilot project many developments were observed and factors noted that influence these phenomena. This exploratory study has raised further questions at many points or crystallised topics that require further examination. These questions are listed in the preceding narrative. They can be grouped into questions regarding teachers, pupils and tools:

For teachers:

- What teaching strategies should teachers use to enable pupils to access the handheld learning tool more quickly?
- How can teaching materials be developed and improved so that integrating a handheld into maths lessons can be supported and encouraged from the start?
- How can the use of different display formats and solution strategies be encouraged in lessons using handhelds?
- How can documentation of solution processes be created and taught when using handhelds?

[6] "Minute Made Math" examples can be found at www.minute-made-math.com.

For pupils:

- How can the use of handhelds to solve many different problems appropriately be supported in each individual's solution and learning process?
- What options for self checking by the handheld do pupils use and how can these be encouraged?
- How can the skills gained by pupils by using a handheld be demonstrated?
- How can problems with operating a handheld (if they occur) be reduced?

For the tool:

- How must a handheld be configured so that it better enables the use of different display formats?
- Can a handheld be configured in such a way that it can be integrated (better) in the documentation of the solution process?

Dr. Ewald Bichler

e.bichler@web.de; ewald.bichler@mathematik.uni-wuerzburg.de