The KAM project: Mathematics in vocational subjects*

Leif Maerker

The KAM project is a project which used interdisciplinary teams in an integrated approach which attempted to connect the mathematical learning to the vocational subjects that the students were taking in a vocational program. The program was a practical one with ordinary teachers working in situations where the day to day problems of schools impacted on the planned implementation. This paper is a summary of and complement to the third and concluding report by Grevholm, Lindberg, & Maerker (2003).

The project took place at Bräcke upper secondary school, a vocational school with a vehicle engineering programme. One purpose of the project was to investigate whether the students could achieve a deeper understanding of both mathematics and the vocational subject if teachers in both subjects collaborated. Another purpose was to analyze, plan and build models for collaboration between vocational subjects and the core subject mathematics in upper secondary school.

This type of collaboration is stipulated in national educational policies but is not as yet a reality in most schools. Teachers in core subjects and vocational subjects generally have completely different educational backgrounds, cultures and views on learning and teaching. As this report shows, there were gains for both students and teachers if interdisciplinary integration was realized to a greater extent than is customary today. The project was funded by The Swedish Board of Education.

Background

The basic 'mathematics A' course was introduced in the 1994 syllabus as compulsory for all upper secondary school students. The aim was to raise the educational level in mathematics among the Swedish population. The course content was designed to strengthen the individual's competence to function as a good citizen in a democratic society as well as reinforcing the student's understanding of the educational components that aim towards the future profession. National policy requires teachers to undertake interdisciplinary collaboration; furthermore, that the teaching of mathematics should ensure that the students can benefit from their mathematical knowledge when studying for their future professions.

Many students in vocational education, especially in the vehicle engineering programme, fail in their mathematics studies. Since up to one third of all mathematics teaching in upper secondary school takes place in the vocational programmes, one of the ambitions of the project was to demonstrate teaching alternatives that might be instrumental in creating an upper secondary school for everyone, using the intended curriculum as a point of departure.

The purpose of the third and final part of the study, the subject of this paper, was to carry out the project's ideas in an entire group of students and with significantly more teachers involved.

The KAM Project Part 1

The first part of the project was a pilot study focusing on the student. Based on the concepts of gear ratio and changes in revolutions in the basic vehicular mechanics course in the vehicle engineering programme and on the elements of fractions/proportionality in Mathematics A, the effects of this integration on students' mathematics results were investigated in two classes. The results indicated that when students understood the mathematical tool that helped explain the gear ratio element, their motivation to study mathematics increased and their performance in the subject improved. The vocational teachers said in their evaluation that understanding and performance in the vocational subject also increased. In addition to the project management, the group consisted of two vocational teachers and two mathematics teachers. You can read more about the project in Kilborn, & Maerker, (1999a) and Kilborn & Maerker (1999b).

The KAM Project Part 2

Part 2 of the KAM project was a continuation of part 1, mainly aimed at teachers developing competence through teamwork in planning the programme. The desired competence development was analyzed and planned. The students' knowledge levels in different areas were studied. Moreover, the group tried out different tests and ideas for education in collaboration with the students. The aim of the project was to build a foundation enabling teachers in all vocational subjects and mathematics, as well as some first-year Swedish language teachers, to collaborate across subject boundaries, applying a process-oriented approach. The group consisted of over ten teachers of first-year students in the vehicle engineering programme.

The results show:

- Students must understand clearly the connection between the vocational subject and mathematics in order to be able to improve their results in both subjects.
- Insufficient collaboration across subject boundaries is experienced as an obstacle to achieving the integration of mathematics education and the vocational subject.
- Teachers at the school value the project highly and are committed to helping the students learn. The project has influenced them to think in terms of collaboration between subjects, but insufficient time and the lack of good, integrated textbooks and teaching aids is an obstacle.

One of the teachers said that his own teaching had been put under the magnifying glass which had helped his development as a teacher. It had been very rewarding to work with the construction of work and test exercises. The systematic examination of the planned exercises was especially good.

The analysis, planning and trials aimed at finding models for collaboration between mathematics and the vocational subject during the first two parts of the KAM project indicated that the work was proceeding in the right direction. The students' motivation and results improved and the teachers were pleased with the development and competence enhancement in which they were involved.

You can read more about the project in Grevholm, Lindberg, & Maerker, (2001)

The KAM Project Part 3

Purpose

The purpose of part 3 was to test, i.e. use, the results of the work done earlier, on a smaller scale, in all the first-year classes at the school. This means coordination of the core subject courses – basic vehicular mechanics course; electricity A; electricity B and driving licence theory – with mathematics and partly with Swedish language. The strengths and weaknesses of the project idea for day-to-day work at the school were comprehensively studied.

Furthermore, the intent was to coordinate the core subject courses with the content in mathematics, and partly with Swedish, at the second-year level. An inventory of teaching material, teaching methods and teacher competencies was to be taken, leading to partial restructure. The teachers' competence was to be expanded.

The study group

The vehicular mechanics programme is divided into transport, lorry mechanics and car mechanics programmes. The car mechanics and lorry mechanics options were in the process of being terminated. The school had about 600 students.

The transport programme has seven first-year classes, six second-year classes and five third-year classes. Over 40 teachers were working in the programme. About 98% of the students were boys and about 30% had immigrant background.

Project team

The project team involved teachers at the school as well as external researchers.

- Project leader: Leif Maerker, lecturer at Bräckegymnasiet, Göteborg
- Assistant project leader: Lisbeth Lindberg, Assistant Professor at the University of Göteborg

- Scientific leader: Barbro Grevholm, Professor of mathematics and learning, at the Engineering College in Luleå
- Teachers: Two in vehicular mechanics, one in transport, two in mathematics and one in Swedish

The plan was that five teachers from outside the project would teach the courses we wanted to study. They took part in the competence development prior to the start of the project but, unfortunately, four of them were unavailable when we started so we had to improvise.

Test Results

The courses we studied were vehicular electronics, the basic transport vehicles course and the basic vehicular mechanics course. Mathematics was a tool for understanding in these courses when it came to pressure, transmission, torque, electricity, velocity and the meaning of average speed. The focus of this paper is on transmission and pressure.

The test results presented here from the transmission and pressure courses are from pre-tests and post-tests that have been analyzed during the project. The control group consisted of over 30 students who took the same course the previous year when the project functioned on a smaller scale and thus did not work with the KAM project model.

Transmission Mathematics

When the subject of drive shaft is covered, concepts such as transmission arise, i.e. the change of torque that occurs between the engine and the driving wheels. Proportionality and inverse proportionality are the mathematical concepts used to describe the change in the number of revolutions occurring in the transmission.

The change of torque occurring between the engine and the driving wheels is inversely proportional to the change in the number of revolutions occurring in the drive shaft. Mathematics is a very important instrument for the students to understand this concept and proportionality is an important item of mathematics for students in the vehicular mechanics programme. Proportionality is the foundation for the calculations in many courses in the programme and it is important in other areas of practical mathematics as well.

In the transmission course, the two mathematics teachers worked somewhat differently. In two classes, the mathematics teacher taught both transmission and mathematics. The vocational teacher was present in class during the teaching of transmission. The teaching of mathematics was organized similarly to the other courses.

In the other classes the teaching was divided; some mathematics teaching took place in the workshop together with the teacher of the subject specific to the programme. The same vocational teacher who took part in teaching the torque course also took part in this subject.

This course also included an interdisciplinary final task that was marked by both involved teachers in order to give the students a clear signal that the subjects formed a unity. In one of the classes, Swedish language was also included in the interdisciplinary task. By focusing attention on the subject specific to the programme and coordinating teaching in Swedish language and mathematics with the vocational subject, we wanted to increase motivation for the core subjects and demonstrate that the combined subjects form a unity in the educational programme. The interdisciplinary task was theoretical; students were required to put an engine of their own choice on a wheelbarrow and arrange the force transmission to the wheel so that the wheelbarrow moved at walking speed. For Swedish, they were required to write a patent application for their “invention”.

The written test on transmission had a maximum score of nine points. Table 1 shows the average score.

Table 1. Results of the transmission test

	58 students (experimental group)	34 transport students (control group)
Pre-test	2.2	
Post-test	5.4	2.1

As in all courses, we observed that the experimental group’s results on the pre-test are at the same level as the reference group’s results on the post-test. The experimental group’s post-test results improved a great deal, compared to pre-test results. This indicates that mathematics is an important tool for the students to absorb this subject as well.

The written test of mathematics had a maximum score of 17 points. The average score is shown in table 2.

Table 2. Results of the mathematics test

	38 students
Pre-test	6.0
Post-test	13.2

The students' knowledge of mathematics as well as their knowledge in the vocational subject improved significantly. Only 38 students participated in both the pre-test and post-test in mathematics, but over 58 students participated in the subjects specific to the programme. The different number of students participating in the different tests presented here is due to the above-mentioned organizational problems, among other causes. Our interpretation of the results is that they clearly show that the vocational subject helps the students to understand these items in mathematics. They also show that mathematics helps the students understand the vocational subject if both subjects are studied in conjunction.

The large improvements in post-test results in this transmission course, compared to pre-test results, are probably due to the KAM project's pilot studies in the course. The material and educational methods are well established and had been developed over some time and the teachers felt confident with the course. During this school year, we had also introduced the interdisciplinary task at the end of the course in order to give the students a signal that the different courses form an entity in their education. A comparison between course results throughout the years is shown below in Table 3. (Due to different group sizes, we have chosen to present the results as percentages.)

The tests in parts 1 and 2 of the project were a part of a pilot study with fewer students. The test in part 1 was targeted to mathematics and hence there are no results from the vocational subject.

Table 3. Improvement (percent) from pre-test to post-test: transmission in mathematics and the vocational subject

	Vocational Subject	Mathematics
KAM project: part 1	-	33 %
KAM project: part 2	43%	14 %
KAM project: part 3	145 %	120 %

The tests carried out during the three parts of the project were changed somewhat since the educational contents and methods evolved during the course of the study.

We observed a clear improvement in mathematics during the period beginning with the school year 1998/99 and ending 2001/2002. The poorer results during part 2 were due to an extremely problematic student group with great restlessness in the classroom and poor attendance.

We observed even greater improvement in the vocational subject. In their evaluations of part 1, the vocational teachers stated that the students' understanding of gearing had improved through the project. We interpret this to mean that a long-term plan regarding the teachers' responsibility in each course is essential, enabling interdisciplinary collaboration which in turn develops the educational programme over a long period of time (Fullan, 1991).

In one of the groups (13 students), integration with Swedish was carried out with a starting point in the interdisciplinary task. All of the students passed the assignment. The following evaluation showed that 9 students thought they had learned what was intended. They appreciated that more than one subject was included in the exercise. That the task took time from other things they needed to learn was one negative aspect, in their opinion. Three students were generally negative to the task.

Pressure – Mathematics

Pressure is included in the introduction to the basic vehicular mechanics course. As with transmission, the subject is important in explaining how a car works. This course is also important in facilitating the students' learning in many other courses.

Pressure is calculated using the formula $pressure = \frac{power}{area}$.

Students should be capable of division in order to calculate the pressure or to study the relationship between force and area. The students should also be able to calculate force if the pressure and area are known. This requires knowledge in handling the formula to create an equation that should subsequently be solved.

During the course, the students make measurements in which different units are used for pressure and force. The connection between these units of measurement is not always obvious to these students; nor is deciding if the result is plausible or not.

The teacher in charge of the vocational subjects had not taken part in the competence development that we ran the term prior to the start of the project.

The pressure course content is difficult to explain to the student from a didactical point of view. In the students' minds, there are two kinds of pressure; pressure exerted on a constant area, for example the ground, and pressure that exists in the brake system of a car. These are regarded as two different entities. The notion that pressure acting on the ground is decreased when the force is distributed over a larger area is simple to show in experiments and relatively simple to acquire intuitively, but understanding a brake system's function is more complicated.

Before teaching began, the students took a test that had been tried out during part 2 of the project (pre-test). When the groups had finished their classes in the vocational subjects, they took the same test again (post-test 1). When the vocational material had been taught, the mathematics teacher explained the same subject in the mathematics classroom but, in contrast to the teaching in the vocational subject, mathematics was used as a tool to explain the material. The subject was also linked to parts that rely on the same kind of thinking. The same pressure test that was given earlier was given again (post-test 2). A test of the areas in mathematics that were included in the course was given at the start of the school year and again after the subject had been studied during mathematics class. Table 4 shows the average score on the test which had a maximum score of ten points.

Table 4. Results of written test in pressure

	Experimental group 17 transport students	Control group 34 transport students
Pre-test	5.0	
Post-test 1	4.9	
Post-test 2	8.0	5.1

As can be seen in Table 4, the students' knowledge of the material included in the test did not improve after the teaching in the vocational subject. The group is at the same level of knowledge as the control group. In order to draw a more definitive conclusion, a qualitative evaluation would be required so that the processes the students used could be documented After the explanations during the mathematics class, the students' knowledge improved considerably. One interpretation is the importance of coordinating the two subjects, ensuring that all teachers have knowledge across the subjects' boundaries and that the student is given clear signals from both teachers that the two subjects are important to facilitate learning.

The mathematics test also had a maximum score of 10 points and the average score is shown in table 5.

In Table 5 we can see an improvement between the pre-test and post-test results in mathematics. Since we are dealing with items we know are difficult for the students to master, these results imply that the collaboration between the different courses has helped facilitate the students' learning in the subject of mathematics as well. The results of the pre-test are high, compared to what we know that students usually accomplish when they reach upper secondary school. This is probably due to the fact that we had covered the different aspects of fractions in the regular mathematics courses before this area was taught in this part of the basic vehicular mechanics course.

Table 5. Results of the mathematics test

	17 transport students
Pre-test	4.1
Post-test	6.8

We acknowledge that the groups are small and that there could be some memory carryover between the three tests. However, the results of the pre-test and first post-test are practically the same, making it unlikely that this led to the

improvement in the second post-test. Thus, these results show a major interaction between the learning in the two subject areas.

Students' Attitudes

Providing the students with a positive attitude towards the subject of mathematics is an important component of this project. The students were therefore given the chance to answer a number of questions regarding their experiences and attitudes towards mathematics both at the beginning and the end of the first school year. Seventy-eight students took part in this survey.

The results indicated that the students understood the use of mathematics to a greater extent than before and that their motivation to study the subject had increased. Their attitude towards the subject had become more positive and their self-confidence had improved.

The Teachers' Evaluation

In connection with the completion of the project, the participants were asked to evaluate the programme.

The positive responses concern the work in the project group, described as interesting and instructive; also, the respondents believe in the idea on which the project is based.

Otherwise, there is a negative tendency in the evaluations. The teachers described how they had been looking forward for a full school year to finally trying the ideas they had been developing for so long. They expressed how they later felt great disappointment when they were denied the opportunity to carry out the task for which they had been preparing. All teachers described how the schedule design and group divisions made the work difficult. One teacher described the chaos that made working in the project a great burden without any rewards. They described how the school management neither showed any appreciation nor supported the participants in their work

Problems and Challenges

One of the purposes of the project was to find a way to develop the education in course A in mathematics in the upper secondary schools' vocational programme. This was to be accomplished in collaboration with the courses in the vehicular mechanics programme in which mathematics is a tool to create understanding of the subjects specific to the programme. The project's point of departure was the schools' curriculum policy. The project philosophy was that its benefits should affect all students at the school and that the development work should emanate from activities taking place in the classroom at the time.

Major change in school management

Since the start of the KAM project, the school management group underwent major changes. These changes at the management level also brought about many organizational changes at the school. This, in turn, influenced the project greatly.

Many researchers claim that improvement attempts in schools often fail because of the present school structure, burdened by tradition, such as weekly schedules and class divisions that render the introduction of promising innovations impossible. It is also emphasized that the cultural and structural changes must be intertwined for the developmental work to be supported (The Board of Education, 2001). These were obstacles faced by this project as well.

Discussion of the KAM Project: Part 3

It is evident that collaboration between mathematics, Swedish and subjects specific to the programme helps the students in vocational education. They become more motivated for their studies and attain better results in the core subjects as well as the vocational subjects if the subjects are didactically formed together in a way that are clear from the students point of view. For the teachers, this collaboration requires expanding their competence and insight into their colleagues' work.. However, this competence improvement does result in greater contentment with work and greater ability to support student progress. The teachers become aware of students' problems and are more prepared to help the students in their learning. The competence of the teacher group and their desire for change is crucial to the outcome of the project.

Partly new evaluation methods are required to make it possible to follow the students' development, since a change in teaching methods has taken place. The teachers must be open-minded regarding the variety and variation in

methods, instruments and models of explanation. Collaboration between the subjects is important for the students to have an opportunity to deepen their understanding of basic concepts. It has become clear that mathematics is an important tool for the students to reach a deeper understanding of the vocational subjects. Similarly, in the context of interdisciplinary collaboration, it becomes evident that the connection to vocational subjects assists in the learning of mathematics.

One condition for carrying out interdisciplinary collaboration is that the school management supports the idea and creates the necessary physical conditions.

References

Fullan, M. (1991). *The new meaning of educational change*. London: Cassell

Grevholm, B., Lindberg, L., & Maerker, L. (2001). *Kam-projektet del 2*. Göteborg: Bräckegymnasiet

Grevholm, B., Lindberg, L., & Maerker, L. (2003). *Kam-projektet del 2*. Göteborg: Bräckegymnasiet

Kilborn, W., & Maerker, L. (1999a). *Karaktärsämnenas matematik*. Delrapport 1 från -projektet. Göteborg: Bräckegymnasiet.

Kilborn, W., & Maerker, L (1999b). *Karaktärsämnenas matematik*. Delrapport 2 från Kam-projektet. Göteborg: Bräckegymnasiet.

Skolverket (2001). Villkor *och vägar för grundläggande yrkesutbildning, några forskarperspektiv*. Stockholm: Liber Distribution.

Other literature that has influenced this paper

Bessot, A., & Ridgeway, J. (Eds.) (2000). *Education for Mathematics in the Workplace.* Dordrecht: Kluwer Academic Publishers.

Ellmin, R. (2000). *Portfolio – sätt att arbeta, tänka och lära.* Stockholm: Författaren och Förlagshuset Gothia AB.

Forsman, B. (1997). *Forskningsetik*. Lund: Studentlitteratur.

Lindberg, L., & Maerker, L. (2000). *TheKAM-projekt.* Proceedings ALM7.

Maerker, L. (2001). *The KAM-project*. ALM Newsletter No. 13.