RÅDET FÖR HÖGRE UTBILDNING
COUNCIL FOR THE RENEWAL OF HIGHER EDUCATION

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Improved learning of basic mechanics by student active teaching methods

Abstract

Background
The teaching of the basic courses in mechanics at Luleå University of Technology is carried out as lessons. However, the tightening of the economic resources has resulted in larger classes and a considerable reduction of the number of lessons. With well over 30 students in the class most of the advantages with lessons are lost. The lessons tend towards formal lectures. The teaching loses in quality and will not be effective for the students' learning.

Aim of the project
Mechanics is a subject in which the theory is very close coupled to our everyday surroundings (e.g. vehicles, constructions, machines etc.). To be able to put the theory into practice a deep understanding is important. The main purpose of this project is therefore to get the student to take a larger responsibility for acquiring knowledge and under-standing, and also gain experiences of how to organise the learning and how to work in groups, i.e. an overall method for studying. A second aim is to make the teaching more effective in that the teacher will be involved mainly in those items which the students find difficult and need help with. Important is then to produce methods to find those items on which the teaching should be focused.

- We expect to have a pedagogical method, which will impart deeper knowledge in mechanics to the students.
- That the students acquire a method to organise their own studies and gain knowledge of working in group, i.e. a universal technique of studying that will be of great use further on.
- A clear picture of what role the teacher will have in this teaching method and in what way the work of the teacher will change.
- Clarity of what the responsibilities for the students are and what the students can manage themselves.

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Department of Mechanical Engineering

Final report on the project

Improved Learning of Basic Mechanics by Student-Active Teaching Methods

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1 BACKGROUND

The teaching of basic courses at universities is in many cases carried out as lessons (by which we mean sessions during which the teacher is lecturing for part of the time and the students are working individually on tasks for part of the time). According to the experience of many teachers and the opinions of the students, this form of teaching works very well as long as the size of the class is less than 25 students, which is confirmed by Professor Graham Gibbs at the Open University in England. The teacher can then conduct a dialogue with the students and receive a response from them, and thus the teacher will the whole time be reasonably aware of what the students have understood and what they have not understood. The teacher can then concentrate on the more difficult parts. This size of class makes the student less anonymous for the teacher, and she/he can keep up with how the individual students are progressing. During the part of the lesson when the students work independently, the teacher has the opportunity to give individual help.

However, the tightening of financial resources has resulted in larger classes and a considerable reduction of the number of lessons. Moreover, at Luleå University of Technology today we plan our lessons in such a way that their contents are on the verge of being too comprehensive given our present pedagogical strategy. This means that the teacher is supposed to present and explain in some detail the essential theory and the most important methods of problem solving. With well over 30 students in the class many of the problems of learning and teaching in large classes mentioned by Ward and Jenkins [1] are emerging (anonymity, no feedback, and passivity, among other things). The teaching loses some of its quality and will not be effective for the students' learning. To compensate for this negative development we worked out a project founded on small group teaching in mechanics with the purpose of introducing elements of active learning and of getting the students to take greater responsibility for their own learning.

2 DESCRIPTION OF THE COURSE

The course in which this project was performed is a 5-credit (7.5 ECT) course in basic mechanics. This course is given during one half-semester in the first year of studies and it is compulsory in all of the four-year Master of Science programmes in engineering at Luleå University of Technology. In parallel the students pursue two other courses, one of which is in mathematics. In each study group there are 30-35 students.

The aim of the course is to impart basic knowledge of classical mechanics concerning the equilibrium of bodies and the motion of particles and rigid bodies in two dimensions. The students are to learn how to apply the methods of classical mechanics in the solution of problems. One laboratory experiment is included in the course. The teaching method is traditional lessons. The assessment of the students is in the form of a traditional written examination composed mainly of problems to be solved, but exercises taken from the laboratory experiment and questions testing the students' understanding of the theory are also included.

3 PROJECT LAYOUT

From our experience of teaching mechanics we think that there is no revolutionary new and simple method to learn a subject like mechanics, in spite of the new information technology. The latter will provide excellent teaching aids, but knowledge must be acquired by the student her-/himself through sedulous work; nobody else can give her/him knowledge. The student must grasp the significance of the physical relations and be able to apply them in a correct way. The main purpose of this project has therefore been to get the student to take a greater responsibility for acquiring knowledge and understanding, as well as gain experience of how to organise her/his learning and how to work in groups, i.e. an overall method for studying. A second aim has been to make the teaching more effective through the teacher being involved mainly in those course segments which the students find difficult and need help with. It is then important to produce methods to find those course segments on which the teaching should be focused. This project has been in accordance with the overall pedagogic idea of Luleå University of Technology, namely that the students' learning comes first and the task of the teacher is to facilitate and support this process.

Mechanics is a subject whose theory is very closely coupled to our everyday surroundings (e.g. vehicles, constructions, machines, etc.). To be able to put the theory into practice a deep understanding is important. Lecturing, which is the conventional teaching method, often results in only superficial knowledge, which is not satisfactory [2].

Many studies have demonstrated that co-operative learning is superior to traditional lectures, see e.g. Ref. [3]. Groups serve as a way to encourage students to be active, facilitate discussion and provide a more co-operative atmosphere in the class. Research evidence, e.g. Ref. [4], also supports the view that active approaches are a more effective way to facilitate student learning. Students are more likely to understand and remember material learned through active engagement in the learning process.

Bonwell and Aison [5] found that active learning is preferable to traditional lectures if the goal is to develop higher-order thinking or change the students' attitudes.

Mechanics should be a suitable subject for active learning in small groups. The students experience mechanics as a difficult subject. There are many abstract conceptions, which they find difficult to grasp but which are of fundamental importance for deep understanding. One example is the concept of force, which forms the basis of mechanics but, nevertheless, many students never master. We think that the ideas of constructivism are suitable in a course like mechanics. The student constructs and creates conceptions and ways of thinking from the surrounding world. By argumentation with the teacher and other students the student will have opportunities to compare her/his understanding with that of other people. This mutual interaction will help the students to acquire the deeper knowledge necessary to be able to put the theory into practice, i.e. acquire a feeling for which physical principles are applicable in a special case.

In Sweden, successful small group teaching in mathematics, which in a sense is closely related to mechanics, has been carried out [6,7].

The outcome of the present project has been evaluated by Rune Olsson at Linköping University.

4 PREREQUISITES AND EXPECTED RESULTS

4.1 Prerequisites

On the basis of the above line of reasoning, the prerequisites for the organisation of the small group teaching in this project can be summarised as follows:

- The students are to acquire deep knowledge. (For an explanation of that conception, see Chapter 6.1.1.3).
- The students are to work in small groups practising active learning.
- The teacher is to be involved in those course segments which the students find difficult.
- The time spent by the teacher with the students is to be the same as before.
- The teaching method must not involve more examination.
- The teaching method must not involve more compulsory course segments.

4.2 Expected results

The results that we expected to obtain from the project can be summarised as follows:

1. We expected to obtain a pedagogical method which would impart deeper knowledge of mechanics to the students, in spite of the teaching time being less than it is today.
2. We expected the students to acquire a method to organise their own studies and gain knowledge of working in a group, i.e. acquire a universal technique of studying that would be of great use further on.
3. We expected to create a clear teaching model that would make it easier for teachers joining the project at a later stage.
4. We expected to develop a teaching model which could be adopted in other subjects and used not only at Luleå University of Technology but also at other universities.
5. We expected to obtain a clear picture of what role the teacher should have in this teaching method and in what way the work of the teacher would change.
6. We expected to elucidate what the responsibilities of the students are and what the students can manage themselves.
7. We expected to learn what kind of problems (practical, social, etc.) we must be prepared to handle.

5 ORGANISATION OF THE COURSE

During the first year of the project two classes of ten took part according to plan. For the second year the original intention was that all the classes studying mechanics during the second half of the spring term would join the project. However, due to an acute scarcity of lecturers at that time, the overall planning of the teaching in mechanics had to be reorganised. For that reason the project started with four classes, but in one of them this teaching method had to be abandoned for reasons mentioned later.

5.1 Grouping

The division into groups was accomplished according to Kolb's theory of learning styles [8]: *convergers*, preferring abstract conceptualisation and active experimentation; *assimilators*, preferring abstract conceptualisation and reflective observation; *accommodators*, preferring active experimentation and concrete experience; *divergers*, preferring concrete experience and reflective observation. A short test revealed what kinds of learning style the students possessed, and groups of four in which the different styles were represented were formed. The students were encouraged to work together throughout the course. The purpose of the co-operation in small groups was to get the students to work together to maximise their own and others' learning. To facilitate solidarity the groups were recommended to generate ground rules regulating their work and their relations to each other.

5.2 Course design

The course in mechanics was organised in the following way, described for a one-week period for one class; and this schedule was repeated for the seven weeks' duration of the course:

Day 1: One introductory lecture (2x45 min) during which the theory that was to be learned during the week was outlined. The purpose of this lecture was to give a structure to the subject and make it familiar to the students before they started their self-instruction, i.e. to help the students to start to acquaint themselves with the course book. It is important that the students should be prepared for this lecture, and they were therefore requested to study for this course segment in advance with the assistance of the distributed reading assignments to facilitate the reading of the textbook.

Day 1-3: The students worked on their own studying the theory and guided by worksheets containing self-evaluation questions, recommended numerical problems from the textbook, problems from past examination papers and directions to supplementary study resources.

To encourage the group work, part of these days was scheduled (totally 3x90 min) and rooms for the work reserved. The teacher acted as a tutor in the learning process and was available for questions for about half of the time according to a schedule, most often during the last part. Thus the groups started to work on their own without a teacher.

The questions and numerical problems were not only of a standard type but were also designed in such a way that they would direct the students to a deep approach.

During the second year of the project, tasks of an experimental nature were introduced. The students received a kit for basic mechanics for setting up simple experiments, thus learning by doing ("hands-on experiments"), giving a connection with reality, so that mechanics would not only be a matter of theory. One experiment each week was scheduled, and the experiments concerned especially topics in mechanics, which we by experience know are difficult for students to grasp.

Day 4: Test on the topic of the week. This test was not compulsory and it was managed entirely by the students. The groups were responsible for the test one week each. The tasks were taken from problems in the textbook and reformulated to test the students' understanding of how physical models should be formed, the meaning of equations, the conditions for their applicability and so on. Only occasionally was the solving of problems demanded. Sixty minutes were devoted to the test. After that the answers were collected, shuffled and distributed again for marking. This was performed according to a system involving numbered test sheets, in such a way that each student marked someone else's test without knowing whose test it was. The students were guided by a marking-template. Finally the marked tests were collected and handed over to the teacher. There was no credit connected with the tests. The purpose was to encourage the students to follow the study schedule and to make them aware not only of what they had grasped, but also what they had not understood, which is also extremely important. The outcome of this test, combined with a written account from the groups of what topics they had particular difficulty in grasping, was then the theme of the next day's lesson. This doubled information from the test and the presentation from the groups guarantees that the teacher is well informed about the progress of the students, and that the students take an active part in their own learning.

Day 5: The outcome of the evaluation on day 4 was followed up. One lesson based on the difficulties revealed in the evaluation was given. The difficult topics were penetrated.

This lesson was originally intended to be what Jenkins calls structured [9]. The teacher started penetrating the subject, but only continued for a short while. Then the students were given a short task to discuss or solve. This procedure was repeated throughout the lesson. In that way the students' level of activity was increased and their attention could be kept on a higher level than in conventional lessons. However, the students found such lessons to be too split-up, and they expressly asked for traditional lessons, and since we had promised to be sensitive to the students' opinions, we met their wishes. Anyhow, the students were highly motivated and receptive during this summarising lesson.

It is important that the students should be prepared for the lecture outlining the subject for the coming week. However, experience shows that the students have difficulties in realising this preparation all by themselves. Therefore, to help the students to commence this work, the last minutes of the lesson on day 5 were devoted to a brief summary of the subject for the coming week.

5.3 Examination

The course was concluded with a written examination composed mainly of problems to be solved, but questions concerning applications and analysis were also included. The course in mechanics is a basic course, whose principal goal is to ensure that the students independently will be able to form relevant equations and perform the necessary calculations for solving problems in mechanics.

Alternative examination methods have been considered but not tested. We have so far not found a method that in a satisfactory way fulfils this goal without increasing the amount of examination.

Continuous assessment is used at Mälardalen University in combination with small group teaching of mathematics [6]. We did not test this form of examination for two reasons. Firstly, it would have resulted in more examination, which is contrary to one of the points in our outline of the project plan. Secondly, much of the time spent by the teacher with the students would have been devoted to examining the students instead of helping and supporting them in their learning process.

Awarding credits on the basis of the tests has been considered but has not been implemented. The tests and the marking of them were carried out completely by the students themselves. We did not find a satisfactory and fair way to award credits on the basis of the tests without giving up the system involving student responsibility for the tests. However, we will investigate the possibilities of alternative examination methods further.

6 EVALUATION

6.1 Pedagogical evaluation

6.1.1 External evaluator.

The aim of this project has been to get the students to take a greater responsibility for their studies and acquire a deeper understanding of mechanics, so that they may be competent to carry out analysis, synthesis and evaluation.

The students have filled in questionnaires and have been interviewed about the extent to which they experienced that the aims of the project were fulfilled in the course in question, compared with what is the case in courses with traditional teaching. All this evaluation was carried out by Rune Olsson, who was in no way involved in carrying through the course.

The aim of the evaluation has therefore been to see if this way of teaching/learning has affected the following three main areas:

- the students' way of thinking when solving problems in physics,
- the students' attitudes and approaches to study,
- the students' comprehension of the concept of knowledge.

The frames of reference and methods are presented in the table below.

	Aim: to see if this way of teaching/learning has affected The students' ….	Frame of reference	method
1	… way of thinking when solving problems in physics	Woods' Components in the Problem-Solving Process (Appendix 1)	Sitting next to the student and listening when the student is solving problems
2	… attitudes and approaches to study	Ramsden and Entwistle: "approaches to studying questionnaires"	Written test before and after the course for all students
3	… comprehension of the concept of knowledge	SOLO taxonomy: Structure Of Learning Outcomes	Interviewing a small number of students

In the first year all three frames of reference were used. Fifteen students were randomly selected for the interviews, which were carried out before and after the course. Of these 15 students, 5 were from each of the two classes participating in the test and 5 were from a control class which was given ordinary teaching. These students had performed differently in previous physics courses.

In the second year we used only the second frame of reference and no interviews were carried out.

6.1.1.1 Ways of thinking when solving problems

The reference frame used is the one presented by Don Woods at McMaster University, Hamilton, Canada [10]. In this model there are 7 steps. (Appendix 1)

1 READ THE SITUATION
2 DEFINE THE GIVEN SITUATION/PROBLEM
3 DEFINE THE "REAL" PROBLEM AND CREATE A REPRESENTATION
4 MAKE A PLAN FOR THE WORK
5 FOLLOW THE PLAN
6 CHECK, LOOK BACK, IMPLEMENT
7 ACCEPT A SOLUTION

In each step of the strategy there are "thinking components" and "attitudinal components". The students were given different physics problems to solve.

When a student solved a problem, each step was identified and given a step number according to Woods' strategy. Each student was given three problems to solve. The sequence was written down. The three results were summarised in one description. The next table shows the summarised result for each student. We also give the results of the examination after the course. The "q" stands for quitting. At this point the student said, "I give up," without coming to a feeling of having solved the task.

For the test classes:

Stud-ent	Exam Grade	Sequence before the course	Sequence after the course
A	U	15q	133q
B	U	135q	123q
O	U	13q	15257
C	3	12456	123453357
D	3	123457	1231357
E	3	235q	133457
F	3	135q	13345q
G	4	135q	123456
H	4	1356	12334567
I	5	1357	1234567

For the control class:

Stud-ent	Exam Grade	Sequence before the course	Sequence after the course
J	U	15q	135q
K	3	12357	12334567
L	3	135q	123345q
M	4	13q	123334457
N	5	12356	1234567

Most students have improved and all those who have passed the exam have improved. There are no differences in the results between the two groups. The teaching method used is not that important when training students how to solve problems. In the interviews the students in the control class gave a great deal of credit to their teacher. This has certainly influenced the result of the evaluation. Another large influence was that 3 of the 5 students from the control class were always studying in groups anyway. These three benefited from having both a good teacher and good fellow students in their group.

6.1.1.2 Approaches to Studying

Ramsden's [11] and Entwistle's [12] "approaches to studying questionnaires" have been used. Each student has given answers to a number of statements before and after the course. The questionnaire can be found in Ref. [13].

We have used the four factors with the highest correlation factors for successful studying. They are the following:

A Achieving orientation

Competitiveness, well-organised study methods, and hope for success.
Students who score high tend to achieve well. (Correlation factor: +0.32.)

B Reproducing orientation

This indicates a superficial approach to learning. Students who score high on this scale attempt to memorise subject matter and are not interested in studying for its own sake, but only out of a concern to pass. They keep strictly to the syllabus as laid down in the course description and do not follow interests of their own, if they have any.

Despite their concern to pass they tend to achieve badly. (Correlation factor –0.25.)

D Meaning orientation

This indicates a deep approach to learning. The student seeks the meaning of the material in use, is involved and active, places his/her own knowledge in the context of real life, does not just study for the exam, is interested in learning for the sake of learning, and is interested in the subject. The student follows his own interests, even if they are outside the subjects in the exam. This student wants to understand what he/she reads and finds interest in the learned. This student is usually successful. (Correlation factor +028.)

Total success TOT

This factor is a combination of all the variables in the questionnaire. It produces a high correlation factor for success: +0.41.

The questionnaire was filled in twice: before and after the course. We give the measurements before and the difference between the two. About 60% have answered both questionnaires.

In order to improve, the student should have an increase in A, D and TOT and a decrease in B.

The results from the first year for both the test group and the control group are presented in the table below. We also give the proportion of students who have improved in this manner (the number of students who have improved/ the total number of students).

	A: MV diff	A: proport of good stud	D: MV diff	D: proport of good stud	TOT: MV diff	TOT: proport of good stud	B: MV diff	B proport of good stud
Test group 1	-1.0	4/16	+1.0	7/16	+1.0	9/16	+0.8	8/16
Test group 2	0.1	3/10	+1.2	7/10	+3.6	7/10	0.0	4/10
Control group	+1.2	7/12	+0.5	7/12	+0.6	5/12	-0.3	5/12
To improve the figure should be	+		+		+		-	

A difference of one unit in A, B, D and TOT is significant.

A Achieving orientation: Only the reference group has improved.
D Meaning orientation: The test groups have improved more than the control group. Maybe discussions in a group increase the students' sense of "meaning".
Total success TOT: The experiment classes change more than the reference class.
B Reproducing orientation: Only the reference group has improved.

The results from the second year are similar and are discussed under "Findings …" below.

6.1.1.3 The students' comprehension of the concept of knowledge

The frame of reference is the SOLO taxonomy and the COL: the Concepts of Learning as presented by Gibbs [14].

SOLO level	Structures of Learning Outcomes	
1	prestructural	No knowledge, "islands"
2	unistructural	One relevant aspect
3	multistructural	Several independent aspects connected
4	relational	Integrated in a structure
5	extended abstract	Generalising to a new area

	Concepts of Learning		
COL level	Learning as ...	Deep	What the student does or says …
1s	… an increase in knowledge	Super-ficial	Gain knowledge, know more, follow the teacher, defensive attitude
2s	… memorising	Super-ficial	Active work, no transformation, filling
3s	… acquiring facts or procedures which are to be used	Super-ficial	Acquire abilities, algorithms, rules are used, no transformation
4d	… making sense	Deep	Active effort to bring out meaning ... the sense, objectives, during the learning process. Transformation
5d	… understanding reality	Deep	Knowledge enables the student to grasp the “world” differently.

The following questions were asked in order to extract the level:

1 What is knowledge to you?
2 How can you achieve knowledge?
3 When a student fails to learn something … fails an exam… what can cause that?
4 Characterise a good teacher.

In Appendix 3 we show a summary of the interpretations of the interviews with the 15 students during the first year. Nine of the 15 students change their level according to SOLO and /or COL, especially students with work experiences. “Deep knowledge” can be interpreted as high levels of SOLO ans COL. The students who have studied in groups have increased more.

6.1.1.4 Findings from the questionnaires and the interviews

Please look at the table in Appendix 2.

We look here at the evaluation for both years. We look only at the students who have been in test classes.

The number of students who have answered the two questionnaires (approx. 60%) is too small to draw firm conclusions. Anyhow some findings suggest that the following might be said.

The students who have a problem-solving style to the left in Kolb's diagram (i.e. who are strong with regard to "active experimentation") tend to work more in groups than students with styles to the right (i.e. who are strong with regard to "reflective observation"): meaning values of 5.8 and 4.3 hours respectively of study per week in a group outside class hours.

The differences in attitudes (TOT) are small as mean values for all the students. When looking at the higher and lower quartile, there are some interesting results. In summarising one can state that those who have succeeded well before (in terms of their previous performance at school and their marks so far at the university) gain more from the new teaching style. Those with good self esteem gain more from the new teaching style. Maybe there has not been enough time to bring about a change to the new approach to studying or to train students in applying the new approach.

The MV for the marks in the written examination spread over the marks from the students' previous school (upper secondary school) are 5a: 9.4p; 4a: 8.8p; 3a: 6.4p. Of course, students with better marks from their previous school are better prepared.

The MV for the hours spent in group work outside the class are 5a: 4.4h; 4a: 5.2h; 3a: 3.7h. Perhaps those who have a mark of 4 from the upper secondary school have a better way of organising their studies and they may have perceived the importance of good group work. This also fits in with the interviews, which showed that students who have a low level of achievement tend to feel that one cannot and will not take up time of the good performers.

6.1.1.5 Sources of errors

One main factor for success in testing new teaching styles is the teacher's ability to adapt and use the benefits of a certain teaching technique. This concerns both the teachers in the test group and the teachers in the control group.

As mentioned earlier, in the control class during the first year the teacher was very much appreciated. In the examination in the first year the first assignment was considered very confusing by the students. In the interview many students claimed that they tried to figure the assignment out, but failed and got confused, and could not give their best performance during the rest of the examination.

6.1.1.6 Recommendations

The new teaching method should be continued! The majority of the students think that they benefit from the tested teaching style.

Give the teachers training in how to help the students to co-operate well in groups. Give the students training in how to organise group work, with regard to both studying and project work.

This can be accomplished, for instance, with Olsson's "Projekt och Grupp" [15] and /or Gibbs' "Learning in teams" [16].

Moreover, it is recommended that some reward should be introduced for the students' group work.

6.1.2 Evaluation at Luleå University of Technology

The evaluation carried out at Luleå University of Technology consists of the outcome of the examination and a written questionnaire, as well as a compilation of the teachers' opinions.

At the end of the course each year the students answered a written questionnaire and during the first year they also answered one in the middle of the course.

The purpose of the questionnaire was to find out what attitudes the students had to this teaching method and their opinions of how the everyday work functioned.

A summary of the outcome of these questionnaires is given in Chapter 6.2.2.1. In Appendix 4 there is a compilation of the answers to the questionnaires from two of the classes (class A and class B) in the second year of the project. A remarkable difference can be noted in the two classes concerning the students' opinions of small group teaching. The class which was more positive (A) was also most successful in the examination. On the other hand, a similar difference in opinion was found between the two classes participating in the first year of the project, but then the class that was more negative achieved by far the best result in the examination!

6.1.2.1 The students' opinions of the course

The most striking fact is that the opinions of the students diverge strongly. Most of the students were positive to this teaching method, but a great many were against it.

In one of the four classes participating in 2001, the project was discontinued, since about half of the students would not take part. Before that decision was taken, we had a discussion with the students about how to continue the course. After that the students were requested to decide what kind of teaching they wanted. By a bare majority they decided after a vote to return to traditional lessons. In the vote all the students except three took part. An interesting observation was that after that the students attending the lessons were the same as those who were positive to small group teaching. Those students who preferred traditional lessons did not come to the lessons even then, although they had said that they would do so.

In the other classes students who did not like the new teaching method stopped coming to the lessons with group work.

The students who did not like the new teaching method gave the following weighty arguments against it:

- There is too little lecturing.
- If you do not co-operate very well with the rest of the group, your results will be poor.
- It is difficult to take in the theory by yourself.
- You have less independence; you have been forced to do this.
- It takes time from other courses.

The first two points sum up the main objections against the teaching method.
The students who expressed those opinions claimed that they studied less and learned less compared with what they would have done with traditional lessons.

The students who preferred this teaching method argued that:

- The benefit of working in groups is large.
- More is accomplished.
- You are “forced” to read the course literature.
- You follow the course syllabus better.
- You get more opportunities to question the teacher and the other students.
- You are aware of what you know and what you must focus on in your studies.
- You have the opportunity to think.
- The time is used more effectively.

These students were of the opinion that they worked harder and learned better/much better with this teaching method.

6.1.2.2 The teachers’ opinions

The experience of the teachers involved in this teaching method can be summarised as follows:

Positive aspects

- It is more enjoyable and stimulating and one's insight into the students' way of thinking is increased.
- The students get their work started better and work continuously during the course.
- The students become aware of strengths and weaknesses in their knowledge.
- The teacher becomes aware of the strengths and weaknesses of the students.
- The follow-up lesson after the test. The students are then motivated and can follow the course better as we go through the subject.
- The teaching method makes demands on the teacher, requiring her/him to take an active interest and improvise.
- The experiments carried out by the students result in practical attainments and in theory being put into practice.

Negative aspects

- In groups which are not functioning (the level of attainment and ambition varies substantially, the members do not have good relations with each other, etc.) the outcome is poor.
- If a student is not able to keep up, this will inevitably be exposed to the group and the student is likely to quit.
- It may be frustrating for the students to find out their weaknesses.
- It may be frustrating for the teacher to find out shortcomings in the students' previous knowledge, which has been taken for granted.
- If there are many students in a class who dislike the teaching method, this will result in a bad atmosphere and disquiet.
- The administration of the course increases.
- Putting together a timetable is more complicated.

6.2 Examination

In the first year of the project the examination was identical for the two classes taking part in the project and the other classes. The project classes achieved the best results, and in one of these classes the number of students who passed was unusually high. It can be noted that in these classes the attendance at the lessons was considerably higher than in classes with traditional lessons. However, since the classes represented different study programmes and were not quite equivalent, far-reaching conclusions should not be drawn from this result.

In the second project year one problem in the examination was specific to the three project classes and one problem was specific to the other classes. The project classes were given one problem connected to the classroom experiments, while the other classes were given one problem from the laboratory work. This year too one of the project classes achieved the best results, but the other two classes were not successful. Some students from these classes accounted for this by explaining that they did not have the time and energy to put into work on the course in mechanics. Other courses (with several compulsory segments) in their study programme, which they had in parallel, demanded too much work, so they dropped the course in mechanics.

By comparing the classes with respect to their results in the examination in the course in mechanics and their results in the examination in the physics course a half-term previously, it can be noted that in the first project year the two project classes raised their results compared with the other classes. During the second year no significant difference could be detected between the project classes and the other classes.

6.3 Results

The outcome of the project compared with the expected results (Chapter 4.2):

1. "Deeper knowledge" has been achieved as interpreted in SOLO (Structures of Learning Outcomes) and COL (Concepts of Learning) levels.
2. The students have received training in organising their studies and have gained experience of working in a group.

3,4. We have acquired a teaching model which, with regard to its essential features, can be adopted in other subjects, and we have also learned how to facilitate for new teachers to join the teaching method.

5. In this teaching method the role of the teacher is changed from that of a lecturer to that of a tutor for the groups. The teacher must be prepared not only to support and encourage the students' learning process, but also to handle problems concerning the co-operation in the groups.
6. The students manifested their ability to take responsibility for their learning in the way in which they started up and carried on the group work on their own in that part of the lesson which was without a teacher. Furthermore, they managed to perform the tests without the teacher being involved.
7. We have learnt to handle practical problems in organising teaching in small groups. In order to overcome social problems, however, time must be reserved for training teaching staff as well as students in group dynamics.

7 DISCUSSION AND CONCLUSIONS

We found that a majority of the students considered that this teaching method worked very well and recommended that the concept should be retained.

Many students were very critical of the method, however, and stopped coming to the lessons or went to classes having traditional lessons. The fact that so many students so strongly opposed this way of teaching leads to the conclusion that it is questionable if one should force this teaching method on students without having the support of the students concerned. Some researchers (see e.g. Ref. [17]) have noted that no single teaching approach is optimal. Therefore, the possibility of offering the students a choice of different teaching methods is worth aiming at, on the one hand traditional lecturing and on the other hand small group teaching.

It has emerged that there is a large turnover of teachers, so that every year there will be many new and inexperienced teachers entering the mechanics course. When practising small group teaching it is an advantage to have experience of teaching the course. With optional teaching methods, one model could involve experienced teachers being responsible for the small group teaching and inexperienced teachers being responsible for providing the more rigid method of traditional lecturing.

One experience from the second year of the project was that many of the groups formed at the start of the course were not preserved, but the students spontaneously formed new groups. Therefore, it would be interesting to test another strategy regarding the group composition. Since the group work concerns solving many smaller assignments of a similar character and not completing a comprehensive project, it is perhaps not very important to have different problem solving strategies represented in a group. Maybe it is more important that the members in the group should have good relations with each other and should be able to work well together. Although permitting students to choose their own groups is not recommended, it can be an alternative worth testing in this case. Special attention and support must then be given to students who tend to be left out.

The purpose of the co-operation in small groups is to get the students to work together to maximise their own and others' learning. Some students, however, do not find this motive for co-operating convincing enough. The main reason for this is that the examination of the course is individual. Not all of the group members are of the opinion that it is important that every one should keep up with the rest, although they may have undertaken to work to this end in the group agreement. To strengthen the co-operative interaction, the introduction of project work running through the whole course parallel to the theoretical part should be tested. The completion of a course project and the report on it would then be one part of the examination. The organisation of the course would in that case have to be changed substantially. Anyhow, students should be awarded credits for the group work in some way.

We want to continue with this project with classes that in advance have taken a positive attitude to the teaching method. Various ways of grouping the students will be tested to find out the most suitable one for this purpose. Introducing project work to encourage co-operation between the students will be considered. Successful elements will be implemented in the traditional lessons, although not in the form of group work. In the long run the students should be able to choose the teaching method that they prefer in a course like mechanics, since students have very diverging opinions about the best way of learning.

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APPENDIX

1 Components in the Problem Solving Process

2 Mean values from both year

3 From the first year. The interviews.

4.Compilation of questionnaire at the Technical University of Luleå (in Swedish)

Appendix 1

Components in the Problem Solving Process. Don Woods: PS News, McMasters University, Dept Chemical Engineering. 1986

	Thinking components		Strategy	Attitudinal components
			PROBLEM	
		1	Read about situation	Anxiety/stress management Motivation/confidence Unafraid of making a mistake
Reason ← Classify Identify series relationships Analogies Consistency	Analysis	2	DEFINE GIVEN SITUATION/PROBL EM	Monitor Systematic Attentive Ability to tolerate ambiguity
Identify Personal Preference ← Structured Knowledge ← Tacit Knowledge Perfom experiments ← Search literature	Evaluate Creativity Generalize Simplify Broaden perspectives Translate Apply heuristics Manage resources Apply criteria Extract and Apply Knowledge Gather new Knowledge	3	DEFINE ”REAL” PROBLEM AND CREATE REPRESENTATION	Ability to tolerate ambiguity Willingness to postpone judgement Open-mindedness Intellectual curiosity, scepticism, honesty Stress management (if get stuck) Unafraid of making a mistake Willing to guess, approximate
	Analysis Resource management Decision making Apply heuristics	4	PLAN	Decisiveness Carefulness Persistent, tenacious
	Analysis	5	DO IT	Careful Systematic Attention to detail
	Communication Creativity Evaluation Generalize Analysis	6	CHECK, LOOK BACK, IMPLEMENT	Intellectual objectivity, honetsy Elation/stress management Motivation Persistance Decisiveness
		7	A SOLUTION	

Appendix 2

Mean values from both year

Table of Mean Values	Age	Sex 1M 2K	Month work exp	Marks Gymn	Point so far	Hours per week in group	Selfesteem Studies 1-10	Selfesteem General 1-10	Chance for CI 1-10	Marks on exam								
Medel	22,8		16,0	4,1	0,8	4,5	7,0	7,2	8,5	7,0	12,8	13,7	13,0	65,9	0,2	0,6	0,3	0,7
Mv Ramsden											13,0	14,3	13,9	66,0				
Ska vara											hög	låg	hög	hög	>0+	<0-	>0+	>0+
1, f1	26,7	1,1	56,2	3,9	0,9	2,8	7,8	7,8	8,7	6,2	13,9	14,0	14,4	68,7	-0,3	-1,0	2,0	4,0
1 f2	22,1	1,7	24,5	3,9	0,8	4,0	6,5	7,1	8,3	8,8	13,2	13,1	13,2	66,5	0,3	0,6	0,0	0,5
1 ref	23,8	1,3	27,5	4,0	0,8	5,1	7,3	7,7	9,1	7,9	15,2	14,1	13,9	69,8	0,2	1,6	0,0	1,1
2 K	25,5	1,6	3,9	3,8	0,6	3,3	6,1	7,4	7,8	1,0	11,4	14,6	11,8	57,4	2,0	0,6	0,4	0,3
2 R	20,8	1,8	0,7	4,4	0,8	4,2	7,2	7,2	8,9	8,5	11,7	13,6	12,1	65,0	-0,3	0,9	0,5	0,1
2 S	21,8	1,8	1,0	4,5	0,8	5,6	7,0	6,6	8,0	4,6	14,5	10,5	13,8	70,8	1,3	-1,7	-2,2	1,0
2 V	21,9	1,2	1,5	4,2	0,9	6,2	7,3	6,6	8,2	6,0	11,8	14,4	12,1	63,6	0,1	1,2	0,3	-0,8
MV K	23,0		14,0	4,3	0,8	4,5	6,9	7,1	8,3	8,9	12,4	13,2	12,6	65,1	0,8	0,2	-0,6	0,4
MV M	23,0		18,0	3,9	0,8	4,9	7,1	7,3	8,7	8,1	13,3	14,2	13,4	66,6	-0,3	1,1	1,3	1,0
A Mv för >17	23,4	1,4	23,1	4,0	0,8	2,9	7,8	7,0	8,9	7,1	18,2	15,1	15,6	73,1	2,1	0,8	1,1	4,7
A Mv för <9	23,7	1,5	10,8	4,1	0,7	4,1	5,9	6,8	7,9	5,6	7,0	14,5	11,1	56,4	-0,8	0,2	0,6	0,6
B Mv för >18	23,1	1,3	3,7	3,8	0,7	4,8	5,7	6,4	6,9	2,3	11,3	18,9	11,8	54,9	1,3	2,5	-0,2	-1,6
B Mv för <10	22,1	1,5	21,3	4,4	0,9	4,7	7,2	7,2	8,7	8,5	12,3	8,5	13,3	71,2	0,2	-0,5	-0,2	0,6
D Mv för >18	23,6	1,5	22,2	4,2	0,9	4,9	8,1	7,0	8,4	7,3	15,8	13,3	18,9	76,4	1,3	1,1	2,4	4,6
D Mv för <10	21,6	1,6	4,3	4,2	0,8	3,6	7,3	7,7	8,9	6,3	11,4	14,5	8,0	55,8	0,9	0,1	-0,8	0,1
Yliv <1mån	20,4	1,5	0,3	4,3	0,8	5,8	7,1	7,0	8,6	7,4	11,9	13,2	12,5	64,3	0,2	0,7	0,4	0,6
Yliv >1år	26,8	1,4	50,8	3,9	0,8	4,0	6,4	7,4	8,1	10,2	13,6	14,4	14,2	67,8	-0,1	0,0	0,4	2,2
SjäStud >8	23,2	1,4	22,3	3,9	0,8	4,6	7,7	8,6	9,5	8,4	13,3	13,5	13,2	67,2	-0,2	0,0	0,4	1,0
SjäStud <6	22,3	1,6	4,5	4,3	0,8	4,0	6,0	5,2	7,2	7,9	11,4	14,6	12,8	62,3	0,5	1,2	0,1	0,4
SjäAllm >8	23,6	1,4	26,9	3,9	0,8	4,6	7,6	8,6	9,3	8,4	13,2	13,5	13,1	67,2	-0,2	0,0	0,3	0,9
SjäAllm >6	22,3	1,6	4,6	4,3	0,8	4,0	6,1	5,3	7,3	8,0	11,4	14,5	12,8	62,3	0,5	1,2	0,0	0,5
Chans >8	22,2	1,4	13,1	4,1	0,8	4,6	7,6	7,6	9,3	9,0	13,1	13,4	12,9	67,1	0,1	0,7	0,6	1,1
Chans <7	24,9	1,6	27,1	4,1	0,7	4,2	5,1	5,8	5,8	5,7	11,8	15,0	13,5	61,9	0,6	0,8	-0,3	-0,6

Appendix 3.

From the first year. Summary from the students that were interviewed.

Student	Class	Strategi FÖRE	StrategiEFTER	Grp ranking	tentaRES	SOLO före	SOLO efter	Dif SOLO		COL efter		år	kön	Yliv	Nat	pHIT	avMöjl	%p	grpTIM	SjäFörHög	SjäFörALLm	Mekp		A	B	D	TOT	Ad	Bd	Dd	TOTd
F	F1	13q 135q	13345q	0	3	2	3	1	2	2	0												k								
H	F1	1356q 156q	12334567	1	4	2	3	1	2	3	1	33	m	150	4			0,7	0	6	8	11.5	r	14	10	14	73	1	1	-1	-6
E	F1	235q 135q	133457	1	3	5	4	-1	4	4	0	20	k	0	5	30	40	1	6	8	8		k	10	14	14	62				
O	F2	13q	15257	2	0	2	2	0	2	2	0	22	M	15	3					5	7	0,5	br	11	15	11	51	4	-5	-1	11
J	Ref	15q 15q	135q	3	0	2	2	0	2	2	0	21	m	12	4	6	40	0,24	7	7	5		k	13	13	17	69				
B	F2	15q 12456	123q	3	0	3	2	-1	2	2	0	22	M	6	4	1		0,8	2	7	8	6	s	16	10	16	81	-2	3	-1	-8
I	F1	135q 1357	1234567	3	5	2	4	2	2	4	2	20	m	0	5	40	40	1,00	2	8	4		s	15	11	18	78				
L	Ref	13q 1345	123345q	4	3	3	3	0	2	3	1	22	k	6	3					5	7	10.5	k	11	13	12	63	1	0	-2	5
A	F2	15q 13q	133q	5	0	3	3	0	3	3	0	40	k	192	4	20	40	0,5	0	5	10		b	11	12	14	73				
D	F2	123457	1231357	5	3	3	3	0	2	3	1	21	K	12	4					6	7	10	g	11	16	12	61	1	-3	2	5
C	F2	156 12456	123453357	5	3	4	4	0	5	5	0	19	k	0	5	40	40	1,00		8	9		b	10	7	12	73				
K	Ref	135q 12357	12334567	5	3	3	3	0	4	4	0	21	M	0	3					8	8	9	k	11	9	11	62	-2	2	-3	-4
M	Ref	12q 13q	12334457	5	4	3	3	0	3	4	1	22	m	12	4	29	30	1,00	14	10	8		s	16	12	15	69				
N	Ref	12356 1235q	1234567	5	5	4	4	0	5	5	0	24	M	50	4			1	12	10	10	14.5	k	16	10	15	77	-1	0	2	0
G	F1	135q 13q	123456	5	4	3	4	1	4	4	0	20	m	0	4	40	40	1,00	14	8	6	13,5	k	9	10	12	63				

Appendix 4

Enkät MTF008 maj –01

Klass A. 31 av 32 kursregistrerade studenter besvarade enkäten.

Närvaro

	alla/nästan alla	75%	50%	≤25%
Inledande lektion	*81%*	*16%*	*3%*	
Övningspassen	*61*	*23*	*13*	*3*
Testet	*42*	*23*	*19*	*16*
Avslutande lektion	*65*	*19*	*13*	*3*

Test

Har testen ökat insikten om vad du kan och vad du behöver arbeta mer med?

Instämmer	Tja	Instämmer inte
65%	*29%*	*6%*

Har testuppgifterna varit

För svåra	lagomt svåra	för lätta
7%	*89%*	*4%*

När du inte är med på testet, vad är orsaken?

- Har inte hängt med 11 svar
- Gått på matteföreläsning 5
- Prioriterat andra viktiga saker 2
- Gjort testet i efterhand 2

Undervisningsmetod

Jämfört med traditionell undervisning tror du att du lär dig

mycket mer	mer	lika mycket	mindre	mycket mindre
13%	*74%*	*10%*	*3%*	

Jämfört med traditionell undervisning tror du att du arbetar

mycket mer	mer	lika mycket	mindre	mycket mindre
16%	*52%*	*29%*	*3%*	

Ange vad du tycker är bättre med denna uppläggning av undervisningen jämfört med traditionell lektionsundervisning.

• Bättre stöd (av kamrater och lärare)	9 svar
• Man ligger i fas med kursplaneringen	6
• Grupparbete är bra	4
• Man vet vad man kan/behöver träna mer på	3
• Testerna	2
• Uppföljningslektionerna, studenterna bestämmer vad som skall tas upp	2
• Man är mer aktiv, får mer gjort	2
• Man får tänka mer	1
• Man får mer gjort	1
• Roligare	1

Ange vad du tycker är sämre med denna uppläggning av undervisningen jämfört med traditionell lektionsundervisning.

• Gruppindelningen ej optimal	4 svar
• Svårt att hänga med om man inte är i fas	3
• För litet lärargenomgångar	2
• Jobbigt med samma grupp varje pass	1
• Arbetssättet passar ej alla, valmöjlighet önskvärt	1
• Det blir mer att lära sig på egen hand	1
• Det blir mycket papper att hålla reda på	1

Har lektionsexperimenten (de som ni gruppvis gjorde) bidragit till ökad förståelse av mekaniken?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
23%	*70%*	*7%*

Övriga synpunkter på lektionsexperimenten

• Bra, lärorika	8 svar
• Roligare att räkna på experiment	3
• Tog lång tid	2
• Vill hellre räkna	1
• Onödiga	1

Litteratur mm

Synpunkter på litteraturen (Meriam-Kraige: Statics, Dynamics)

• Bra, OK	20 svar
• Jobbigt med engelskan	5
• Mycket text	5
• Dyr	2
• Svårläst	1

Läsanvisningar

Har läsanvisningarna varit till hjälp vid inläsningen?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
27%	*53%*	*20%*

Synpunkter på läsanvisningarna

• Har ej haft tid att läsa anvisningarna	7 svar
• Bra	5
• Borde vara mer kortfattade	2
• Lagomt utförliga	1

Arbetsanvisningar

Har arbetsanvisningarna varit till hjälp vid inlärningen?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
80%	*20%*	

Synpunkter på arbetsanvisningarna

• God hjälp vid planerandet av egna arbetet	9 svar
• Bra med tips om hur man skall angripa uppgifterna	8
• Bra	4

- Ger hjälp att förstå 1

Prioritering

Hur har du prioriterat mekanikkursen i förhållande till andra kurser under läsperioden?

Högt	medel	lågt
50%	*43%*	*7%*

Hur mycket arbetar du utanför schemalagd tid per vecka? Ange antal timmar …………

Tim/vecka	0-1	2-4	5-7	≥8	Ej svar
Antal studenter	4	14	7		6

Gruppindelning

Hur tycker du att gruppindelningen bör göras?

På det sätt som gjordes (problemlösarstil, ”romben”)	Studenterna väljer själva	Genom lottning
43%	*37%*	*20%*

Allmänt

Om nästa års klass (inom samma program) får välja mellan denna typ av undervisning och ”vanlig” fysikundervisning vad skulle ni rekommendera dem att välja?

- Denna typ (smågruppsundervisning) 93%
- Traditionell lektionsundervisning 7%

Vad kan förbättras inför nästa års undervisning?

- Gruppindelningen 6 svar
- Längre tid för testerna 4
- Lärargenomgångarna, så att studenterna kan föra anteckningar 3

Vad är viktigt att behålla från detta undervisningssätt till nästa års mekanikundervisning?

- Allt 3 svar
- Grupparbetet 3

- Lektionsexperimenten 3
- Arbetsanvisningarna 3
- Testen 3
- Schemalagda ”hemararbetspass” 2
- Planeringen 1
- De korta genomgångarna 1
- Möjligheten att få räkna mycket själv på lektionerna 1
- Dialogen student-lärare 1

Övriga synpunkter

- Bra med ”lösninspårm” till uppgifterna 3 svar
- Det blir mycket papper att hålla reda på 2
- Önskvärt med varierat upplägg under kursen 1
- Ej så stor skillnad i förhållande till ”vanlig” lektionsundervisning 1

Enkät MTF008 maj –01

Klass B. 27 av 29 kursregistrerade studenter besvarade enkäten.

Närvaro

	alla/nästan alla	75%	50%	≤25%
Inledande lektion	*70%*	*11%*	*11%*	*8%*
Övningspassen	*48*	*26*	*11*	*15*
Testet	*30*	*19*	*15*	*36*
Avslutande lektion	*63*	*15*	*4*	*18*

Test

Har testen ökat insikten om vad du kan och vad du behöver arbeta mer med?

Instämmer	Tja	Instämmer inte
38%	*50%*	*12%*

Har testuppgifterna varit

För svåra	lagomt svåra	för lätta	ej svar
11%	*74%*		*15%*

När du inte är med på testet, vad är orsaken?

- Har inte hängt med 9 svar
- Andra studier och prioriterat annat 7
- Arbetssättet passar ej 2
- Gjort testet i efterhand 2

Undervisningsmetod

Jämfört med traditionell undervisning tror du att du lär dig

mycket mer	mer	lika mycket	mindre	mycket mindre
4%	*30%*	*22%*	*22%*	*22%*

Jämfört med traditionell undervisning tror du att du arbetar

mycket mer	mer	lika mycket	mindre	mycket mindre
	48%	*19%*	*30%*	*3%*

Ange vad du tycker är bättre med denna uppläggning av undervisningen jämfört med traditionell lektionsundervisning.

- Grupparbete är bra 10 svar
- Man får tid att räkna 6
- Lektionsexperimenten 2
- Man får tänka mer 1
- Testen 1

Ange vad du tycker är sämre med denna uppläggning av undervisningen jämfört med traditionell lektionsundervisning.

- För litet lärargenomgångar 8 svar
- Genomgångarna för korta/snabba 3
- Det tar för mycket tid (för mycket schemalagt) 3
- Gruppen gör att man arbetar mindre 2

Har lektionsexperimenten (de som ni gruppvis gjorde) bidragit till ökad förståelse av mekaniken?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
13%	*67%*	*20%*

Övriga synpunkter på lektionsexperimenten

- Svåra 4 svar
- Bättre genomgång efteråt önkvärt 4
- Bra 2
- Ger bättre förståelse 2

Litteratur mm

Synpunkter på litteraturen (Meriam-Kraige: Statics, Dynamics)

- Bra 14 svar
- Svårläst 6
- Jobbigt med engelskan 2
- Dyr 1

Läsanvisningar

Har läsanvisningarna varit till hjälp vid inläsningen?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
23%	58%	19%

Synpunkter på läsanvisningarna

• Bra	4 svar
• Har ej haft tid att läsa dessa	4
• Har över huvud taget ej läst litteraturen	2
• Det blir för mycket papper att hålla reda på	2

Arbetsanvisningar

Har arbetsanvisningarna varit till hjälp vid inlärningen?

Ja, i hög grad	I viss mån	Nej, litet/inte alls
44%	*48%*	*8%*

Synpunkter på arbetsanvisningarna

• Bra	4 svar
• Ger struktur till övningspassen	2
• Kan vara svåra att förstå	1
• För omfattande för ett arberspass	1
• Många svåra uppgifter	1

Prioritering

Hur har du prioriterat mekanikkursen i förhållande till andra kurser under läsperioden?

Högt	medel	lågt
27%	*55%*	*18%*

Hur mycket arbetar du utanför schemalagd tid per vecka? Ange antal timmar …………

Tim/vecka	0-1	2-4	5-7	≥8	ej svar
Antal studenter	6	6	3	2	10

Gruppindelning

Hur tycker du att gruppindelningen bör göras?

På det sätt som gjordes (problemlösarstil, ”romben”)	Studenterna väljer själva	Genom lottning	Ej svar
44%	*41%*		*15%*

Allmänt

Om nästa års klass (inom samma program) får välja mellan denna typ av undervisning och ”vanlig” fysikundervisning vad skulle ni rekommendera dem att välja?

- Denna typ (smågruppsundervisning) 41%
- Traditionell lektionsundervisning 41
- Ej svar 18

Vad kan förbättras inför nästa års undervisning?

- Mer lärargenomgångar 8 svar
- Lägre tempo 4
- Färre uppgifter per gruppövningspass 2
- Kortare tid för testen 2
- Fler experiment 1
- Separata pass för experimenten 1
- Mer lättlästa böcker 1
- Sammanfattning önskvärd 1

Vad är viktigt att behålla från detta undervisningssätt till nästa års mekanikundervisning?

- Lektionsexperimenten 9 svar
- Testen 7
- Tid att räkna själv på lektionen 5
- Arbetsanvisningarna 2
- Gruppindelningen 2
- Grupparbetet 1

Övriga synpunkter

- Bra kurs för de motiverade, jobbig för de omotiverade
- Teorigenomgångarna ger inget, däremot bra när läraren räknar igenom problem
- Undervisningsformen borde spridas till fler institutioner, då den får studenterna att tänka.