

## Interactive lectures in engineering education

L. A. VAN DIJK<sup>†\*</sup>, G. C. VAN DEN BERG<sup>‡</sup> and H. VAN KEULEN<sup>§</sup>

This article discusses an alternative approach to lecturing: the interactive lecture. In the literature, interactive teaching is forwarded as a means to increase the effectiveness of lectures. Members of lecturing staff still seem, however, reluctant to incorporate interactive teaching in their classes, as interaction reduces the time they can devote to explaining subject matter. Lecturers often voice the concern that they will not get enough material across in interactive lectures and that this consequently will negatively affect student learning. In order to establish whether or not the concerns of lecturers could be empirically verified, an experimental study was conducted. This study examined the effects of interactive teaching in lectures, using an interactive voting system and peer instruction, on: the attainment of learning objectives; student motivation; and student perception of the instruction offered. From the results a complex picture emerges. Results suggest that students may learn as much in interactive lectures compared with traditional lectures, but a traditional lecture may also result in active student involvement. The study indicated that interactive teaching will not *automatically* result in students who are more activated, and provided additional insight into conditions for successful interactive teaching. Finally, interactive teaching was shown to influence positively student motivation.

### 1. Introduction

Delft University of Technology (DUT) is the oldest technological university in the Netherlands. At present seven faculties offer 15 engineering curricula, eight of which are unique in the Netherlands. The heart of the first-year curricula consists of courses in beta sciences, such as mathematics, mechanics and physics. These courses are followed by courses in specific applied fields and practical exercises; only after students have mastered the basics, is application of knowledge and skills discussed. Sadly, teachers of more advanced engineering courses often complain that too many of their students lack knowledge of basic techniques, understanding of simple concepts and the ability to apply the knowledge learned in the first year appropriately.

This problem is, however, partly inherent to organization of the curricula, in which numerous mutually isolated courses are programmed, often using a traditional lecturing approach. Bales (1996) estimates that, in the long term, students

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<sup>†</sup> Tilburg University, Department of Research Methodology, FSW, P.O. Box 90153, 5000 LE Tilburg, the Netherlands.

\* To whom correspondence should be addressed.

<sup>‡</sup> Educational Development Unit, Delft University of Technology, the Netherlands.

<sup>§</sup> IVLOS, Institute of Education, Utrecht University, the Netherlands.

will remember merely 5% of the information provided in a traditional lecture. This contrasts sharply with retention rates of 50 and 75% for discussion groups and practical exercises, respectively. In this article an alternative approach to lecturing is discussed, which may increase the effectiveness of a lecture.

Psychological research has shown that learning of subject matter requires that students are actively involved with the material, instead of just listening and 'consuming' the information provided by the teacher (Biggs 1996). It is claimed that students across the educational spectrum understand studied material better, retain it longer and enjoy their classes most when they learn actively rather than passively (Bonwell and Eison 1991, Murray and Brightman 1996). Active learning methods contrast with passive learning techniques that typify the traditional lecture.

To activate students in lectures, the monologue of the lecturer must be interrupted. Active learning in the context of a college classroom can be defined as 'anything that involves students in doing things and thinking about the things they are doing' (Bonwell and Eison 1991: 2). Active learning might include a spectrum of activities, from a modified lecture format to role-playing, simulation and games. Previous case study research conducted by the authors showed that it is possible to activate students in lectures, even though students do not expect to be activated and they seem to prefer traditional lectures to activating ones (Van Dijk *et al.* 1998). Working on problems, Peer Instruction (PI) and using a voting system in lectures were recommended as promising methods for interactive teaching. Indeed, some practitioners have begun to publish examples of uses of interactive teaching methods, reporting their success, including examples from the teaching of engineering subjects (Liebman 1996, Mazur 1997).

Nevertheless, there still is a large gap between educational research and what actually happens in practice. Only too often we see that in lectures the lecturer still talks and the students are required to sit and listen. A survey among university teaching staff at a technological university in the Netherlands showed the average engineering lecturer still tends to concentrate on covering the content and explaining subject matter (Van Dijk *et al.* 1999). This result was similar to the results of an observational study of Vinke (1995) at two technological universities in the Netherlands. Vinke observed 16 members of teaching staff and found they were teaching in a traditional way, using 80% of class time for transmission of information.

For a lot of engineering teachers, teaching seems equivalent to lecturing (Jochems 1996). There seems to be a commonly shared perception among lecturing staff that large classes are likely to preclude significant student participation. In addition, a lot of lecturers are reluctant to accept claims on the merits of activating instruction, which can be found in educational theory. Activating students requires time, which lecturers would normally devote to lecturing. They often voice the concern that they will not get enough material across when giving interactive lectures and that this consequently will negatively affect student learning. It seems that members of lecturing staff are reluctant to accept claims on the merits of activating instruction, which can be found in educational theory. In order to establish whether or not the concerns of lecturers could be empirically verified a small-scale experimental study was set up, in which the effects of interactive teaching in lectures were tested within the context of a traditional engineering curriculum.

## 2. Design of the experimental study

The experimental study was set up to examine the potential direct and short-term effects of interactive teaching in lectures on the attainment of learning objectives, on student motivation and on student perception of the instruction offered. The design of the experiment can be characterized as a pre-test post-test control group design with two experimental conditions. First-year students were randomly assigned to one of the three conditions of the experimental study. Students in each experimental condition attended a lecture on the subject of 'conservation of angular momentum for rigid bodies' given by the same lecturer. The treatment of the three groups involved in the experiment was related to the way the lecturer discussed the subject matter. The lectures were identical as far as the subject matter was concerned. The lecturer had submitted an extensive description of the three lectures involved in this study beforehand and was expected to adhere strictly to this description. The time reserved for the lectures was the same in each case: 90 min.

In order to verify that the students in the three experimental conditions did not differ significantly on relevant prior knowledge of the subject matter a pre-test was conducted. At the end of the lecture a post-test was administered on the lecture content. Students were also required to complete a questionnaire in which the lecture was evaluated. Each lecture was observed by four observers. Three observers were used for high inference observations. One observer used a low inference observation instrument.

As mentioned earlier, the experiment involved two experimental groups and one control group. Students in the control group attended a 'traditional lecture', consisting of a monologue by the lecturer. In that lecture the lecturer never solicited input from students. The lecturer was not supposed to ask questions. If questions were asked, they were of a rhetorical nature and students were not invited to reply. The lecturer was allowed to answer questions put by students. Both experimental groups had to attend a lecture in which they were activated. In these experimental groups the lecturer used the IVS<sup>®</sup> Interactive Voting System<sup>1</sup> and PI to activate students. These interactive instructional methods are described now.

The Interactive Voting System IVS<sup>®</sup> is an interactive means of presentation and communication which can support large group interaction (Schijven *et al.* 1997). IVS<sup>®</sup> consists of a series of electronic voting devices that presenters can use to keep in contact with their audience. Because the audience can react to the presenter and the presenter can react to the various responses of the audience, it is possible to create and sustain interaction within a large group. In a lecturing setting IVS<sup>®</sup> provides lecturers with the opportunity to ask questions about the subject matter, which students can answer anonymously using their voting devices. The results of the voting session can be projected on to a screen, thus making it possible for the students to see them. The lecturer can then give feedback to the student answers. In this way the role of the students changes from being passive listeners to being active participants.

Peer instruction is an instructional method aimed at exploiting student interaction during lectures and at focusing students' attention on underlying concepts

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<sup>1</sup> This article includes a word which is or is asserted to be a proprietary term or trade mark. Its inclusion does not imply it has acquired for legal purposes a non-proprietary or general significance, nor is any other judgement implied concerning its legal status.

(Mazur 1997). Using PI in lectures implies departing from the traditional lecturing format. Instead of presenting the level of detail covered in the textbook or lecture notes, lectures consist of a number of brief presentations on key points, each followed by short questions on the subject under discussion. The students are first given time to formulate answers and then they are asked to discuss their answers with each other. The advantage of these 'convince your neighbour discussions' is that they break the monotony of traditional lecturing and make students think for themselves and put their thoughts into words.

The first experimental group attended an interactive lecture in which the Interactive Voting System IVS<sup>®</sup> was used. The lecturer asked questions, which students could answer anonymously using their electronic voting devices. The voting results were then displayed and the lecturer provided feedback on the results of the voting session. A total of 6 IVS questions was asked in the lecture. Note that the six IVS questions asked in the experimental groups were also rhetorically asked in the control group lecture. The IVS questions stimulated students to think about the subject matter just explained and to apply this knowledge to a presented problem. An example of a question is presented in figure 1.

The second experimental group was activated using PI in combination with IVS<sup>®</sup>. The same six IVS questions were put to the vote twice. After the first voting session, the results were displayed, but no indication was given of the correct answer. The students were then given the opportunity to discuss the questions with each other. After the second voting session, the correct answer was displayed and the lecturer gave feedback.

It was expected that students in the second experimental group (referred to as IVS + PI group) would be the most activated, because they would not only have to think about the subject matter, but they would also be forced to make their knowledge explicit in the discussion with other students. In addition, it was expected that

**A disc with moment of inertia  $I_z$  rotates with angular velocity  $\omega$  and moves with velocity  $v$ . The distance from the center of mass to both points A and B is equal to  $d$ .**

**Which of these statements is true?**

- 1)  $H_A > H_B$
- 2)  $H_A = H_B$
- 3)  $H_A < H_B$

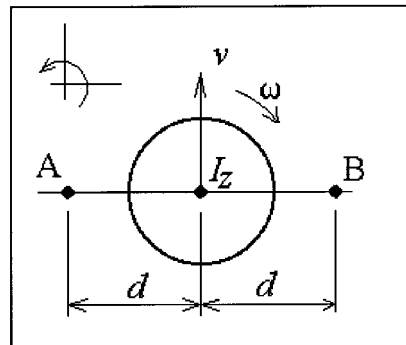


Figure 1. Example of IVS question used in the experimental study.

students in the control group would be the least activated, because there the lecturer had provided them with all the answers to the questions. Students were not explicitly invited to think deeply about the subject matter.

### 3. Instruments used

Students involved in the experimental study completed a pre-test and a post-test in order to determine their level of prior knowledge and their attainment of the learning objectives, respectively. Both the pre-test and the post-test consisted of 10 multiple choice items, with four possible answers. The items of both tests were matched to the learning objectives of the lecture in order to ensure content validity. The pre-test tested students' ability to apply their prior knowledge on 'conservation of angular momentum' to mechanical problems in situations that did not involve rigid bodies. The post-test consisted of items for which students had to use the knowledge they had acquired in the lecture to solve the presented mechanical problems. The pre-test was administered in the lecture on mechanics that was given prior to the experimental lecture. The post-test was administered directly after the experimental lecture. The total number of students who completed the pre-test as well as the post-test amounted to 86.

In addition to completing the pre-test and the post-test, the students completed a questionnaire in which the lecture attended was evaluated. The questionnaire was completed in the first tutorial session following the experimental lecture. For two experimental conditions this meant a delay of 1 day between the experiment and the completion of the questionnaire. For one group the delay amounted to 2 days (IVS + PI group). The questionnaire was filled in by 106 students, 71 of whom also completed the pre-test and the post-test. This paper reports on the questionnaire results of this group of 71 students.

The questionnaires differed for each of the three experimental groups. The control group was required only to answer general evaluative questions concerning 'good lecturing practices' and questions about their motivation for the lecture attended. The students in the experimental groups that received the experimental treatment answered the same evaluative questions and some additional questions relating to the use of IVS<sup>+</sup> (+ PI) in lectures.

Each of the experimental lectures was observed by four observers. One observer made field notes, which were translated into an observational table in which all the didactic events taking place each given minute were recorded. In this way, the observation instrument became a combination of both time and event sampling. The same instrument had already been used in a previous case study research conducted by the authors (Van Dijk *et al.* 1998) and it had proved to be relatively reliable ( $k = 0.72$ ).

Three other observers used a high inference observation instrument, containing 15 items. This instrument enabled the observers to give overall judgements on various aspects of the lecture on a scale of 1 to 5. The lecturer was rated on the following aspects: stimulating student involvement; positive affectivity (creating a friendly and interactive atmosphere); and quality of the lecture. In case study research the latter two aspects of lecturing performance were shown to be necessary preconditions for activation in lectures (Van Dijk *et al.* 1998). Furthermore, the students were scored for their reactions to positive affectivity, for their involvement in the lecture and for their comprehension of the subject matter. Inter-observer reliability was estimated using the Pearson correlation coefficient. The reliability of the

instrument can be regarded as fair, as the correlations between pairs of observers ranged from 0.49 to 0.71.

4. Results

4.1. Prior knowledge of the students

Since the students involved in the experiment attended various courses on mechanics for 9 months, it was desirable in the context of this study to check their general prior knowledge on the subject of mechanics. The combined student results from three exams on mechanics were used as an operationalization of their general knowledge of mechanics. Comparisons between the mean scores of students in the three groups showed that the three groups were comparable where general subject matter knowledge is concerned ( $F = 0.20$ ,  $df = 2$ ,  $77$ ,  $p = 0.823$ ).

A pre-test was administered to ascertain the level of students' direct relevant prior knowledge on the subject. A group of 109 students completed the pre-test. Because 86 students in this group also completed the post-test, the results gained from these 86 students will be reported in this paper. Both the control group and the IVS + PI group contained 35 students. The IVS group was smaller: it contained 16 students.

The eight-item pre-test had a reliability coefficient of  $\alpha = 0.46$  (two items were deleted because of low item total correlations). The removal of two of the pre-test items did not affect the content validity of the test. Considering the number of items and the observed standard error of measurement, this reliability can be considered acceptable (Lord 1959). However, the results must still be interpreted cautiously because of the relatively low reliability coefficient. The pre-test scores of the students in the three experimental conditions did not differ significantly ( $F = 1.61$ ,  $df = 2$ ,  $81$ ,  $p = 0.205$ ). It was concluded that the students in the three groups had comparable prior knowledge.

4.2. Observational results

For each of the three lectures the lecturer used all the time allocated for the lecture (90 min). From the low inference observations based on time sampling, it may be concluded that the lectures indeed do differ with respect to activation initiated by the lecturer and by the time devoted to lecturing (see table 1). From table 1 it can be concluded that the control group was activated the least (11%), whereas the IVS + PI group was activated the most (37%). Note that the lecturer violated the procedure decided upon for the control group, by initiating activation for 11% of the total time.

Group	Transmission of information (%)	Activation by lecturer (%)	Activation by students (%)	Other (%)	Total	$N_{\text{minutes}}$
				(%)	(%)	
Control group	79	11	5	5	100	88
IVS	63	30	1	6	100	89
IVS + PI	50	37	3	10	100	93

Table 1. Results observation using time-sampling method.

High inference observation results showed that the three experimental lectures vary only significantly with respect to the experimental treatment and its effects on students (see table 2). Lecturing behaviour on relevant preconditions (positive affectivity and quality of the lecture) was comparable in the three groups.

From the results of both high inference and low inference observation, it can be concluded that the implementation of the experimental conditions was realized fairly. In the control group student involvement was far less stimulated than in the activating lectures. In addition, the IVS + PI group is regarded as being more activating than the IVS group. As the three experimental conditions were similar in other relevant educational aspects, it seems plausible that possible differences in student motivation and student learning from a lecture can be attributed to the experimental treatment.

#### 4.3. Student perception of the instruction offered

Student perception of the instruction offered was measured using a student questionnaire. Mean results for each group on the sub-scales of the questionnaire are displayed in table 3. From table 3 it can be deduced that the lecturer was scored posi-

	Descriptive statistics			Results analysis of variance		
	C	IVS	IVS + PI	F	df	p
<i>Lecturer</i>						
Positive affectivity	4.08 (0.14)	4.00 (0.43)	4.08 (0.72)	0.29	2, 6	0.972
Stimulating student involvement	1.22 (0.19)	3.00 (0.58)	3.56 (0.19)	32.82	2, 6	0.001**
Quality of lecture	3.44 (0.84)	4.11 (0.51)	3.33 (0.33)	1.48	2, 6	0.300
<i>Students</i>						
Positive affectivity	3.00 (1.00)	3.00 (1.00)	3.33 (1.15)	0.10	2, 6	0.906
Stimulating student involvement	2.00 (—)†	2.75 (0.35)	4.00 (0.00)	45.00	2, 6	0.006**
Quality of lecture	2.83 (0.76)	3.75 (0.35)	3.67 (.76)	1.44	2, 6	0.321

\*\* *p*-Values significant at  $\alpha = 0.01$ .

†Because this score is based on one observer, calculation of the standard deviation for this aspect was not possible.

Table 2. Descriptive statistics for the three groups on the observational aspects of high inference observation and the results of the analysis of variance (scores ranging between 1 (lowest) and 5 (highest)).

	Descriptive statistics			Results analysis of variance		
	C	IVS	IVS + PI	F	df	p
Quality of lecture	3.93 (0.61)	3.90 (0.48)	3.92 (0.46)	0.19	2, 67	0.982
Positive affectivity	4.37 (0.45)	4.33 (0.46)	4.40 (0.41)	0.14	2, 68	0.872
Activation	3.59 (0.60)	3.72 (0.68)	3.90 (0.55)	2.02	2, 68	0.139
Student involvement	3.84 (0.78)	3.69 (0.80)	3.79 (0.54)	0.21	2, 68	0.814

Table 3. Descriptive statistics for the three groups on the subscales of the student questionnaire and the results of the analysis of variance (scores ranging between 1 [lowest] and 5 [highest]).

tively on all aspects of the lecture; mean scores for each group are higher than the 'neutral score' of 3.

Students' evaluation of preconditional aspects with respect to activation was very positive. The lecturer scored about 4 on 'quality of the lecture' and on 'positive affectivity'. From this result it can be concluded that, not only from the perspective of the observers but also from the perspective of the students, the lectures met the needs of good quality and a positive atmosphere. Differences in student learning and student motivation can therefore not be attributed to differences in these preconditions.

The three groups differed on the questionnaire sub-scale 'activation', as was expected beforehand; the students in the control group were the least stimulated to be actively involved with the subject matter, whereas the IVS + PI group was the most stimulated. On the sub-scale 'student involvement', however, the differences are not as was expected. The students in the IVS group were the least activated, whereas the control group contained the most activated students. The differences on both these sub-scales of the student questionnaire are, however, not statistically significant. This result is striking, as the observers did report statistically significant differences between the groups (see table 2). In the field notes of the high inference observers it was remarked that the lecturer tried to keep students attentive in the control group using humour and non-verbal behaviour. After the control group lecture the lecturer remarked to one observer that he was not accustomed to giving a monologue without initiating student involvement. Consequently, he purposefully used humour in the control group because of the 'boring nature' of the lecture. The results on the student questionnaire showed that he was successful in his attempt.

Closer inspection of the questionnaire results of the items relating to activation showed that students in the three groups were equally involved where thinking about subject matter was concerned. This can be considered quite an achievement of the lecturer, as the decreasing attention of students is often cited as a problem of traditional lectures (Newble and Cannon 1989). For mechanical subjects, however, thinking about the subject matter is not enough, as students must learn to apply the theoretical knowledge to various mechanical problems. Hence, students must be involved in doing things with the subject matter. The questionnaire results showed that the students in the three groups differed on one item with respect to activation: 'I was stimulated to take part in this lecture'; students in the control group scored statistically significant lower scores on this item than students in both experimental groups. From the questionnaire results it can be concluded that activating instruction stimulated students' involvement in doing things.

#### 4.4. *Effect of activating instruction on student learning*

Student learning was measured using a post-test on the content of the lecture. The seven-item post-test had a reliability coefficient of  $\alpha = 0.50$  (three items of the originally 10-item post-test were removed because of their low or negative item total correlations). The content validity of the post-test was not affected by the removal of these three items, as the learning objectives of the lecture were sufficiently addressed by the remaining items. Again, the results must be interpreted cautiously because of the relatively low reliability coefficient.

Analysis of the post-test scores showed that the experimental groups differed significantly (see table 4). The experimental group in which IVS<sup>2</sup> was used without PI had significantly lower post-test results compared with the results of both the



	Descriptive statistics			Results analysis of variance		
	C	IVS	IVS + PI	F	df	p
Post-test (7 items)	4.82 (1.50)	4.00 (1.71)	5.23 (1.31)	3.84	2, 83	0.025

Table 4. Descriptive statistics for the three groups on the post-test and the results of analysis of variance.

other groups. The control group and the group receiving IVS<sup>a</sup> in combination with PI did not differ significantly on the post-test results.

The lower post-test scores of students in the IVS group is surprising. It may be explained by the difference in active student involvement reported by the observers. The observers who made high inference observations reported that the students in the IVS group were very passive compared to the control group and students in the IVS + PI group. From the observational results it can be concluded that students in the IVS group were almost equally passive compared to the students in the control group (see table 2). The field notes of the observers reported that the IVS students were even more passive than the students in the control group when it came to 'using opportunities to initiate student involvement'.

Note, however, that the reported lack in passivity is not perceived by the students themselves. Analysis of student response on the evaluative questionnaire showed that students in the three experimental groups did not evaluate or perceive the lectures differently and the reported active involvement was similar. This absence of a significant difference in student perception may be explained by the fact that the students evaluated only the active involvement initiated by the lecturer, whereas the observers explicitly took students' initiative to initiate their own involvement into account. For the IVS students, their lack of initiative (e.g. asking questions for clarification) may be an explanation for their poorer results on the post-test.

It is interesting to see that the IVS students, who attended a stimulating and interactive lecture, showed such a lack of involvement compared with the students in the other groups. This observed lack of student activity is most likely caused by the expectations students have of lectures. Research conducted in Finland showed that students' perception of learning is related to their evaluation of the educational process (Lonka *et al.* 1997). According to Butler and Winne (1995), these differences in perception of the educational process will result in differences in involvement and performance. Indeed, the study of Lonka *et al.* (1997) showed that the active student involvement of students results in better student performance when students' teaching perceptions are congruent with university teaching practice. The expectations of the students involved in the experiment with respect to lecturing were studied in earlier case study research (Van Dijk *et al.* 1998). These expectations could be grouped into three categories: orientation to subject matter; activation of students; and transmission of information. It was possible to compare the expectations of the students in the three groups using a selection of the data from the case study research (only students involved in this experiment were selected). The expectations of the students in the three groups of the experiment are displayed in table 5. From table 5 it can be concluded that the expectations of students in the control group were almost identical to those of students in the IVS + PI group. Students in the IVS group have a different pattern in their expectations,

	Descriptive statistics			Results analysis of variance		
	C	IVS	IVS + PI	F	df	p
Orientation (2 items)	4.46 (0.59)	4.67 (0.33)	4.48 (0.53)	0.68	2, 61	0.510
Transmission (3 items)	3.85 (0.53)	3.69 (0.69)	3.85 (0.52)	0.39	2, 61	0.679
Activation (3 items)	3.04 (0.75)	2.58 (0.82)	3.04 (0.64)	1.93	2, 59	0.154

Table 5. Descriptive statistics and results analysis of variance of student expectations about lecturing behaviour of the lecturer.

especially where activation is concerned. The students in the IVS group do not expect to be activated in lectures in the way that students in the other two groups do. The difference between the three groups is, however, not statistically significant.

Note that each of the categories with respect to student expectations contains only a small number of items. Consequently, differences in student expectations could not be established very well. Nevertheless, it is important to consider the trend in the results which, though not significant, seems to confirm the assumption that active student involvement and consequently student learning are influenced by students' expectations about education.

It must be stated here that the relative passivity of the students in the IVS group should be considered as *habitual behaviour*, instead of a fixed characteristic of the students themselves. In general, students are not accustomed to being put to work in lectures. From the teaching conception results of the students in the IVS group it can be inferred that the passivity of these students can be attributed to the fact that the lecture did meet their expectations and that they were unfamiliar with the interactive teaching method. As a result, they may not have known how to deal with the new teaching situation. From the present experiment it can therefore be inferred that it might be important for lecturers to tell the students beforehand what they can expect from the lectures they are going to attend. Future research must, however, provide further insight into this subject matter.

4.5. Effect of activating instruction on student motivation

With respect to the effects of activating instruction on student motivation no significant differences were found between the groups involved in the experiment (see table 6). The motivation of students can be considered good in all three experimental situations.

This absence of a general effect on students' motivation may also be caused by students' absolute judgements. On the other hand, lecturing performance in the control group was fulfilling student expectations very well. Because students expect information transmission and to be orientated to the subject matter rather than activated (see table 5), it is possible that the evaluation for the control group lecture was as good as that of both other lectures. This ceiling effect prevented us from establishing the surplus of activation as the lecturer was already evaluated well.

When students were specifically asked about the use of IVS<sup>2</sup> and PI in lectures, this provided insight into the effect of activation in lectures on student' motivation. Students indicated that they were very positive about the effects on their involvement and motivation. They indicated that using an interactive voting system (+ PI)

	Descriptive statistics			Results analysis of variance		
	C	IVS	IVS + PI	F	df	p
General motivation (4 items)	3.53 (0.77)	3.96 (0.52)	3.68 (0.61)	1.65	2, 64	0.200
Evaluation of activating instruction (8 items)	—	3.89 (0.52)	3.54 (0.46)	2.15	1, 39	0.037

Table 6. Descriptive statistics for the three groups on motivation and the results of analysis of variance.

in lectures stimulated them to think more about the subject matter and caused them to remain more attentive during the lecture. It must be noted here that students in the IVS group were significantly more positive about the effects of using an interactive voting system in lectures compared with students in the IVS + PI group. This is striking considering the results from high inference observation. From these observations it emerged that the students in the IVS group responded less to the lecturer's attempts to activate them than students in the IVS + PI group. So far, no explanation for this inconsistency has been found. Student response to questions specifically linking IVS (+ PI) and motivation indicated that students think activation in lectures makes these lectures more useful and more fun. They preferred activating lectures to 'normal' lectures.

## 5. Conclusions and discussion

From the results of this study a complex picture emerges with respect to the effect of interactive teaching. First of all, it can be concluded from the results of the IVS + PI group that lecturers' concern that less lecturing and more activation in lectures would result in less student learning is not supported by the present study. Students may learn as much in a traditional lecture as in an interactive lecture. A traditional teaching style in lectures is, therefore, not an essential prerequisite for student learning. However, the study also showed that a traditional lecturing style, in which the lecturer tries to activate students in a more *implicit* way, using e.g. humour and non-verbal behaviour, may also result in active student involvement. Finally, the results of the IVS group showed that interactive teaching will not *automatically* result in students who are more activated compared with students in traditional lectures.

The combined results of the student involvement in the three groups empirically confirm the theory of Kyriacou and Marshall (1989), which states that it is important to distinguish students' activities from students' cognitive experiences. Hence, it is possible that interactive teaching will not automatically result in active cognitive experiences. A student may, for example, choose not to think deeply about the questions the lecturer asks. Similarly, traditional lecturing behaviour will not automatically result in passive students who are accepting the information offered without thinking critically about it.

It must be stressed here that the results of this experiment do not imply that activation is superfluous. Even though it is possible for students to be mentally active during lectures while listening to a teacher's exposition, the chances are that more

students will be more mentally engaged when involved in learning activities like reading, writing, discussing and problem-solving.

From a motivational point of view it can be argued that activation in lectures is desirable. Questionnaire results showed that students who were activated in lectures were very positive about activating instruction. They liked activation, they found it very useful and thought it would contribute to their learning. These positive evaluation results might imply a positive effect of activation on student learning in the long run. If the students enjoy activation lectures, they may be more inclined to be involved in the subject matter, not only during lectures but also at home (self-study). Not just time devoted to study activities may benefit from the motivational effect of activating instruction, but the quality of the study activities may also be positively influenced by activating instruction. In various studies a prominent role is attributed to students' motivation where students' learning strategies are concerned (Biggs 1987, Marton and Saljö 1984, Entwistle and Ramsden 1983). Students' motivations are expected to regulate these strategies and thus the quality of students' study behaviour. A longitudinal study of Vermetten *et al.* (1995) showed that the use of particular learning strategies varied in function of particularities of the learning context. More specifically, changes in study behaviour of students from a surface approach towards a deeper approach (Marton and Saljö 1984) were related to the learning context, which increasingly became of a more activating nature.

Additional insight into preconditions for successful interactive teaching was obtained from the IVS group, in which the students were relatively passive when it came to initiating student involvement. Lonka *et al.* (1997) have already showed the importance of students' expectations with respect to lecturing practices. Although a trend could be seen in the data, the relationship between expectations and involvement could not be established unequivocally in the study presented here. Nevertheless, the trend in the data seems to implicate that for interactive lecturing practices, giving a good quality lecture and creating a friendly and interactive atmosphere are not enough. It appears to be important for lecturers to be explicit about their lecturing style and the purpose of their working method. Lecturers also have to be explicit about their expectations concerning the role of the students in the lecture, as it appears to be important for students to take initiatives (e.g. asking questions) when they do not follow the lecturer's line of argument. Also, it can be inferred from the results of the IVS group that some students may need time to get used to the new lecturing format. Further research is, however, required to provide more insight into this subject matter in order to support this conclusion. A replication study might, for example, study student involvement when lecturers' expectations have been made explicit and students have become used to interactive lectures. Such a study can also provide additional information on the IVS condition of the experiment. It is interesting to see whether or not the results presented here will be found again in a replication study. Interesting questions are, for example: If students in the IVS condition are more involved, will this result in better test results? Will the IVS condition still have students who are less involved? Will students in the IVS group still have poorer results compared to the other students?

Finally, we would like to note here that this study has provided some valuable insights into the effect of interactive teaching in an engineering context. Nevertheless, it needs to be stipulated that the conclusions of this study are still tentative, as the experiment concerned a short intervention of one lecture. It remains unclear what the real impact of a series of interactive lectures might be. The results of this

study appear, however, promising. Interactive teaching in lectures may potentially be an effective approach that deserves, and requires, more in-depth study in the near future.

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### **About the authors**

*Liesbet A. van Dijk* presently works at the Department of Research Methodology at Tilburg University, the Netherlands. The study described in this article is part of her PhD study on activating instruction in lectures, which she conducted at Delft University of Technology, the Netherlands.

*Gerard C. van den Berg* works at the Educational Development Unit, Delft University of Technology, the Netherlands, specializing in the professional training of academic teaching staff.

*Hanno van Keulen* is employed at the IVLOS Institute of Education, Utrecht University, the Netherlands, also specializing in the professional training of academic teaching staff.

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