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Learning More with Demonstration Based Education?*

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The purpose of this case study is to present an alternative way of teaching, using demonstrations as a teaching aid. A system for visualisation and demonstration of fluid mechanics, particularly laminar and turbulent flow, has been developed, used, and evaluated in a basic fluid mechanics course for students in Mechanical Engineering. The idea underlying the demonstrations was to enhance the students' conceptual understanding of phenomena that emerged in fluid mechanics. In order to investigate the outcome, we asked the students from two different groups to fill out a questionnaire in a 'cross-sectional' manner. The results indicate that demonstration-based education had increased the students' motivation and probably enhanced their learning. This could imply that the student moved from a 'surface approach' to a deep-level approach to learning.

Keywords: active learning; conceptual understanding; demonstrations; fluid mechanics

INTRODUCTION

ENHANCING STUDENTS' LEARNING can be addressed in various ways, one of which is to vary the teaching situation. This is also an important factor according to the phenomenographic approach, which claims that variation is the key to supporting a deep-level approach to learning. As teachers in an engineering programme in Sweden, our aim with this paper is to introduce a new way of teaching that is based on demonstration, i.e. demonstration-based education. Another aim is to investigate and illustrate the students' feelings and thoughts about demonstration-based education. The quotation below illustrates the basic assumptions underlying a phenomenographic approach.

> The analysis was initially performed in order to obtain a description of the processes and outcomes of meaningful learning from the perspective of the learner. As regards the processes of learning, these were later interpreted as indicating the existence of surface and deep-level approaches that are connected, respectively, to an atomistic and a holistic approach [2].

Phenomenography is now established as a theory of learning, and the most significant contribution to the field of learning is the concepts of deep-level approaches versus surface approaches to learning. In the last thirty years, these concepts have been thoroughly investigated, particularly in the areas of pedagogy and health sciences, see e.g. [3, 4], but recently also in engineering [5].

The deep-level approach to learning is all about gaining understanding, seeing the phenomenon in a holistic manner and relating things to each others, whereas a surface approach might be described by an atomistic view of learning focused on, for instance, reproducing facts seen as separate parts.

The most significant factors affecting the approach to learning in terms of surface and deep levels (freely translated from Karlsson, [6]) are:

A surface approach to learning is stimulated if the student experiences:

- a heavy workload;
- heavily scheduled timetable;
- few opportunities for deeper studies;
- lack of options for subjects and design;
- examinations aimed at reproducing knowledge and facts.

A deep-level approach to learning is stimulated if the student experiences:

- good teaching, i.e. with sharp feedback;
- clear goals regarding the aims of the course and what is expected of the student;
- time for individual studies and exchanges with other students;
- a 'need' for knowledge along with an opportunity to influence the material'
- a reference to the students' own structures of knowledge and their experiences.

As teachers in an engineering programme in Sweden, our aim with this paper is to illustrate a new way of teaching. The teacher–student interactions are often directed one way, from teacher to student, and the students are expected to listen and

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pay attention to the verbal communication from the lecturer.

Fink and colleagues [7] address the importance of thinking about learning and teaching in a more scholarly way:

> If we want to introduce meaningful change in how engineering education is practiced throughout the profession, faculty members will need a new perspective into why learning about teaching is important, i.e., motivation that comes from the culture, as well as opportunities to engage in what and how to learn about teaching, e.g., a systematic way for continual educational development.

This quotation illustrates the importance of a joint enterprise—if the ambition is to change the educational system, good practice in isolated groups makes the education better, but only for a few. This problem has been addressed by considering collaborative learning methods together with remote education [8].

De Graff and Christensen [9] claim that today's engineering schools have a reasonable variety of teaching in their education programmes. However, what is missing is a critical overview of the different types of didactics and their aims and goals. This could imply that all too often there are factors out of the teacher's control that determine the teaching and thus the students' learning outcomes.

The aim of this study is to present an alternative way of teaching Fluid Mechanics using demonstrations as a teaching aid, and to investigate the associated educational effect from a learning perspective. The students' points of view are central, especially their feelings and thoughts about demonstration-based education as a catalyst for a better phenomenological and conceptual understanding [10, 11]. The teacher perspective is also important, however, since it is the teachers who have experience from other teaching modalities and can thus compare, relate, and evaluate alternative learning aids.

DEMONSTRATION IN FLUID MECHANICS AND ITS ROLE IN THE LEARNING PROCESS

Phenomena related to fluid mechanics are very often experienced in our everyday life: the wind blowing, possibly swirling around leaves and dust; water flowing in rivers; and convective cooling during warm summer days, to mention a few. Many of those phenomena are of practical, physical and/or technological importance as they affect us on a daily basis as well as having a great impact on the design of, for example, cars, aeroplanes, pipe systems and so on.

Despite the practical impact of fluid mechanics, it is also, at least when we view it traditionally, quite a theoretical topic. Students are introduced early on to models and equations of flow and flow phenomena, while experiences of 'real flow', facilitating a conceptual understanding, are for the most part rare. This also emphasises the importance of relating the real world problem to the theory/model world [12]. At more advanced levels, a high level of advanced mathematics is necessary to understand and solve the set of equations describing the flow situation. There is a danger that the students lose track of the physics 'spoken' by the models/equations [13], and that they fail to relate the theory to the real phenomena, causing among other things a lack of conceptual understanding, giving them a surface approach to learning [14].

In order to bridge this gap, we planned to move towards what we call a demonstration-based education in fluid mechanics courses at the undergraduate level. Within this concept a more clear and present connection between the physics of the flow and the models attempting to describe this physics are important [15]. We believe that the education programme should depart from physical phenomena that use the students' earlier experiences and understanding, and that live demonstrations/visualisations are a good tool for acquiring an improved 'feel' for the physics as earlier indicated [11]. The demonstrations/visualisations would thus serve as catalysts for a deeper understanding, as well as being a part of the students' experiences while discussing theories and models describing the flow.

DEMONSTRATION SYSTEM

In order to carry out the demonstrations, we developed a system for flow visualisations. We had access to a system for Photo Image Velocimetry (PIV) [16], which was subsequently improved and adapted to a teaching situation.

The system basically takes pictures of small particles in the flow illuminated by laser light. The laser light is aimed at the flow by lenses that diverge the laser beam in one direction forming a 'laser sheet' that is about 1 mm wide in one direction and increasing from 4 mm in the other direction (Fig. 1). The laser sheet illuminates seeding particles that have been added to the fluid flow. A camera is placed perpendicular to the laser sheet, capturing pictures of the flow, or, more specifically, of the illuminated seeding particles.

The flow is obtained by two water containers connected to a pipe (the flow system is not included in Fig. 1). Water is led from one container through the pipe, and ends up in the second container via a nozzle at the end of the pipe. By varying the water flow, nozzle shape and size, and by placing different objects in the jet exiting from the nozzle, a large number of interesting flow situations can be studied.

The system also comprises a computer with specially designed software for camera control, image capture and visualisation and laser control.

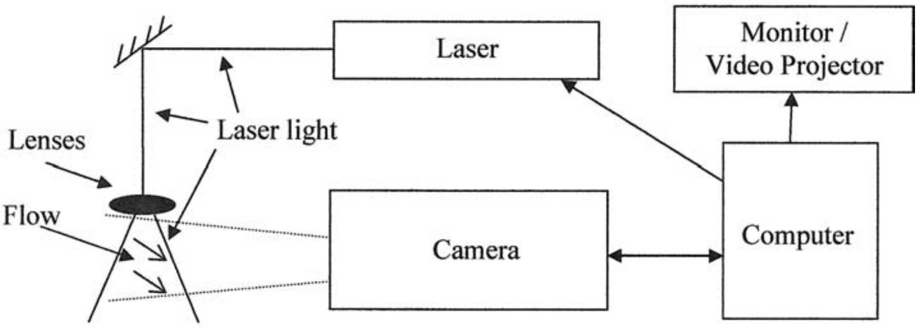

Fig. 1. The flow visualisation system.

For example, the laser can be modulated (pulsed) and the camera can be controlled in terms of the length of the exposure time and frequency, which makes it possible to adapt the system to various flow speeds and geometries. The software has a very user-friendly interface, which makes the system very pleasant to work with in the teaching situation. It is, for example, easy to place various objects in the flow and adopt the system to the new visualisation situations.

CONTEXT OF THE STUDY

The students included in this study were at the end of their second year in the 4.5 year Mechanical Engineering programme). They had so far mainly attended mathematics, solid mechanics and other basic engineering courses.

Education in the programme takes the form of lectures, lessons and laboratory sessions when appropriate, although in some courses some of the lectures and/or lessons are replaced by seminars. In a typical engineering course, 40–50% of the education is carried out as lectures, 40–50% as lessons and 5–10% as laboratory experiments.

The lectures are normally dominated by one-way communication from teacher to students as the students are supposed to listen and take notes. Asking questions is not prohibited, but is not very common; thus this educational design makes the students relatively passive. During a typical lesson, 25% of the time is taken up by a summary during which the teacher briefly discusses theory and solves a few standard problems. The students then work with problems on their own, discussing problems with each other and with the teacher.

The laboratory sessions are mainly based on 'mechanical hardware', although computers have been introduced as an alternative in recent years. Lab sessions normally last 2–4 hours and consist of assignments solved in groups of 3–5 students. There are often some preparatory tasks for the students to work with before the lab, and students are often asked to write a report describing how they solved the assigned tasks and answer the preparatory questions etc. following the lab. A traditional seminar at the Institute of Technology can be seen as a mix of lecture and lesson.

METHOD

Sample and survey

This study had a cross-sectional design and consisted of two groups of students answering a questionnaire (Q). The questionnaire consisted of questions about what the students thought of the demonstrations, if they were worth the time etc. All the students in the study attended the same lectures but were in different classes. The two classes were chosen randomly out of four possible classes; each class (investigated group) had about 24 students.

Each student in the survey answered the questionnaire on two occasions: before and after the demonstration. One of the two groups had been given an introductory lecture on basic fluid mechanics before the demonstration, while the other group were given the same lecture, but after the demonstration. Thus, a total of four questionnaires were used, see Fig. 2 for an outline.

Both the demonstration and the lecture were about basic fluid mechanics, discussing laminar and turbulent flow and factors influencing them at an introductory level.

This design for the study gave us the opportunity to investigate whether the timing of the demonstration relative to a lecture discussing the theory influenced the students' perception of the demonstration. For example, it might be expected that students who had some theoretical background before the demonstration might see the phenomena demonstrated in a different light than students who did not have the same preconceptions.

Analysis

The surveys were independently analysed by four teachers, who read them and reflected over the students' answers to the surveys. Subsequently, the teachers discussed the answers in depth, trying to find similarities and differences in the students' statements. Finally, the differences and similarities

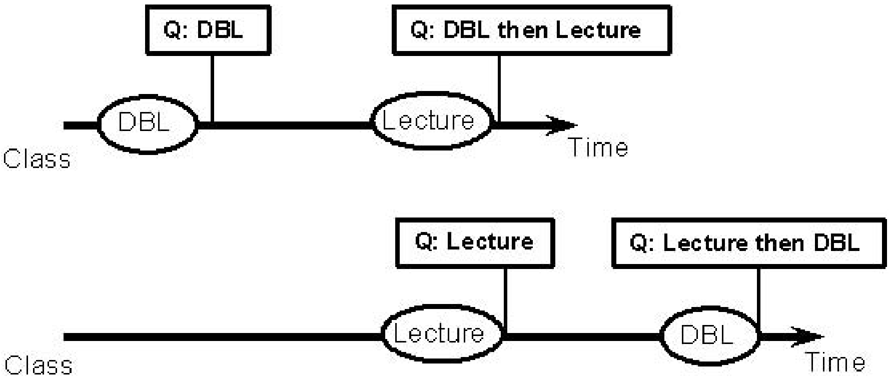

Fig. 2. Chronological order of the questionnaire relative to the lectures and demonstration-based learning (DBL).

were divided into categories. The results are illustrated by quotations, which serve as examples of the 'main opinion' as well as showing some interesting deviating opinions along with a discussion of the material.

RESULTS

The results are divided into two sections based on the students' and the teachers' perspective, respectively.

Student perspective

The answers in the three groups investigated—'Demonstration based learning (DBL)', 'DBL then lecture' and 'Lecture then DBL'—are categorised within each group. Quotations illustrating the students' perception of DBL are given, after which an analysis is presented for each group. The section ends with a concluding analysis of all the material analysed.

Demonstration-based learning

This group of students had demonstration-based learning (DBL) as their first experience of teaching. They filled out the questionnaire directly after the demonstration.

Inspiring

> 'You are able to see how something works in real life. Your interest increases in teaching situations that differ from the normal ones.'
>
> 'Interesting to see in real life the things that you normally only calculate.'
>
> 'It gives me a good experience and it increases my motivation to study the subject.'

Theory and practice

> 'It's good having practical examples, it's easier to understand the theory.'
>
> 'Gives a better feel and a clearer picture than reading a book.'

Gain understanding

> 'Better understanding, something to relate to.'

Analysis (DBL): Most of these students seem to have a value-oriented study strategy; they express the value of having something to relate to, whereas the student in the first quotations argue based on a difference—namely, the different teaching situations.

DBL then lecture

This group of students had DBL as their first experience of teaching followed by a lecture on the subject. They filled out the questionnaire directly after the lecture.

Theory and Practice

> 'It's more interesting to see how it works in practice.'
>
> 'You can connect theory with reality and in that way increase understanding.'

Power of visualisation

> 'You remember what you have seen (not heard) more easily.'
>
> 'Seeing it in real life and not only schematically, the knowledge is acquired more easily and stays longer.'
>
> 'Interesting to see how it works in real life, even if you probably forget everything very fast.'
>
> 'It's good to get an 'image' to relate to when you discuss it later.'
>
> 'You get a feeling that what we have calculated on actually exists.'
>
> 'You don't have to read books.'

Analysis (DBL then Lecture): The category 'theory and practice' is a category that most students mention; probably this category reflects the students' need to have something to relate to. An interesting point is the students' answers concerning keeping the knowledge intact, i.e. remembering. This student group filled out the questionnaire one week after the demonstration; this is probably the reason why many students in this group emphasise the memory aspect of the demonstration. 'You don't have to read books'. What does this imply? One answer could be that the student found a relief in a new teaching situation or that he/ she feels pressured about the reading load.

Lecture then DBL

This group of students had the lecture as their first experience of teaching followed by DBL. They filled out the questionnaire directly after the demonstration.

Theory and practice

> 'It's easier to see in practice compared to just the theory.'
>
> 'It makes it a bit easier to combine theory with reality.'

Power of visualisation

> 'It's easier for me to visualise what is really happening.'
>
> 'It's good to have an image of how the differences between the laminar and turbulent flow appear.'

Charming

> 'If it's really boring, it lightens it up, it could also give more understanding.'
>
> 'It's a refreshing complement in subjects that are heavy loaded with theory.'
>
> 'I think that demonstration-based learning is a very good complement to normal lectures.'

Analysis (Lecture then DBL): In addition to the value of this teaching method, the students refer to emotions, the feeling of experiencing something new and exciting. It is charming, it lightens up etc. are all factors that can help the students to achieve a more deep-level learning strategy.

Teacher perspective

The amount/intensity of questions asked by the students during the demonstration did not differ so much from a traditional lecture. However, we observed a different type of question from those normally asked. The students noticed different flow phenomena, both planned and some that 'just happen to be there', and were curious about what they saw and what caused it. Other common questions concerned what would happen if something were changed, e.g. the object in the flow, thus reflecting thoughts that probably would not arise during a traditional lecture. Furthermore, we observed a high level of activity among the students during the demonstration, which is positive. The questions also made us reflect on inserting various geometrical shapes as well as objects of different sizes, e.g. cylinders with different diameters, into the flow to further explain the phenomenon.

Immediately after the demonstration, the students were very interested in the setup. They wanted to see it close up and ask questions face-to-face with the instructor as well as with the demonstrator. The questions were both about the demonstration setup and the flow phenomenon just visualised. Thus, it seems as if the demonstration increased their curiosity and resulted in thoughts and questions that focused on the phenomena and the underlying physics rather than on difficulties associated with new words, mathematical operations, and things 'regarding the presentation' However, we did not observe any more intensity in questions about flow phenomena such as turbulent and laminar flow in the lessons following the demonstrations. This can probably be explained by the fact that the students saw the demonstration as a stand-alone event, which would not help them to pass the course. Furthermore, the teachers observed no changes in types of questions and thoughts from the students during the lessons that followed. This indicates either that the demonstration did not leave any questions and thoughts or, as mentioned, that the demonstration was more or less a stand-alone event in this course.

Concluding analysis

There are some minor differences between the groups; however, some categories are still to be found in all the groups. Different study strategies seem to be present in the whole cohort. Some students express themselves in a fashion that could be explained as reflecting 'the classical student'. These students emphasise the value of theory and practice gained from the demonstration, whereas other students emphasise the experience of learning, using words like, fun, charming etc.

Most of the students expressed satisfaction with the new teaching aid as a complement to the normal teaching methods. It also provided the students with an image of a phenomenon that is usually hard to grasp, and some students explained the importance of having such an image. The images give the students a memory to use in their future studies and perhaps working life. The device gives the teacher the opportunity to interact and influence the flow. The demonstration is a 'live performance' that differs from that from technical equipment such as videos, TV and animations.

Similar to the reasoning above is the students' relief at seeing a phenomenon in real life. Usually, the students calculate, read and listen; now they had the opportunity to see a phenomenon. This experience is not very common in education today.

DISCUSSION

When designing a course, there are some questions that ought to be considered. The question is, for whom is the course designed, what is to be learned, when should we provide the course, why should we learn and how should we design the learning experience?

The aim of the demonstration based education described in this paper was to give the students, in their first year in the programme, an experience of a physical phenomenon that is difficult to grasp when teaching using just words (lectures). By visualising this phenomenon, the students gain access to the 'same' experience as the teacher and their knowledge production could, with a few aids, develop into a creative discussion. In most types of education, the teacher is the bearer of knowledge and usually knows more about the subject. However, there is a difference in how teachers use their knowledge. In different faculties/subjects/disciplines, there are different conditions for teaching and learning.

According to Northedge [17], the students need to learn to think and speak the discourse, i.e. the way we in a department speak about a phenomenon such as teaching, the implicit and explicit rules we have to adhere to etc. The teacher has an important role in this process; he/she is an expert who should support the students in acquiring the tools necessary to create a meaning in this new discourse. By using visualisation, the teachers' aim was to provide the students with a 'picture of the real thing', to see the flows and, as a result, realise that different flows have different consequences for, for example, the environment. Biggs [18] argues that to facilitate learning, the teaching environment can contribute by:

- teaching in such a way as to explicitly bring out the structure of the topic or subject;
- teaching to elicit an active response from students, e.g. by questioning and presenting problems, rather than teaching to expound information;
- teaching by building on what students already know;.
- confronting and eradicating students' misconceptions;
- assessing for structure rather than for independent facts;
- teaching and assessing in a way that encourages a positive working atmosphere, so students can make mistakes and learn from them . . . (pp. 17).

Hopefully, the students had gained a better understanding of the phenomenon of laminar and turbulent flow, which enables them to identify the different flows and have a mental representation they can use later on in life. When analysing the questionnaires, the students were found to have a positive attitude towards this teaching form, they liked the visualisation simply because it differed from the usual teaching. They also said that they had acquired an understanding of the phenomenon and could relate theory to practice.

The teachers observed and reflected on this 'new' teaching aid in order to enhance and improve the teaching aids in the following courses. The most interesting reflection that occurred during the demonstration-based teaching was that the students asked questions that seemed to be the result of curiosity. By this, we mean that they were of a more explanatory nature.

Finally, using visualisation as a teaching aid seems to be a good way of enhancing the students' motivation and interest in the subject. There are the benefits from both student and teacher perspectives when students get involved in their own learning process [19]. Letting the students see and experience a phenomenon instead of giving them a traditional lecture (using words and, at best, a projector with text and charts) enhances their motivation to study and improves their learning. By discussing with the students, we can create a collective body of knowledge and challenge each other in the production of future knowledge.

CONCLUSIONS

Demonstration-based education has been found to contribute positively to teaching and learning in basic fluid mechanics education.

The students who we investigated say that their interest and curiosity had increased, which could indicate that they are moving towards a more deep-level approach to learning. However, to maintain this they need to be challenged and to experience variation in their educational setting.

By watching a phenomenon live, the students can experience and visualise a phenomenon that would be hard to grasp solely from a text. Using demonstrations could promote greater understanding and the students might make use of their conceptions of laminar and turbulent flow in real life (in their future professional lives). It is possible to move from more traditional teaching to demonstration-based teaching with the minimum support of aids and, by doing this, create a change in the students' learning strategies.

REFERENCES

1. L. Svensson, F. Marton and L.-O. Dahlgren, *Inlärning och omvärldsuppfattning* (in Swedish), Prisma förlag, Stockholm (1999).
2. Project Journeymen, Students as Journeymen between Communities of Higher Education and Work—final report. Fifth Framework Programme; European Commission; Brussels, Project number: HPSE CT-2001-00068 (2005).
3. M. Bendz, *Kunskap i praktik* (in Swedish), Pedagogiska Institutionen, Lunds Universitet, Lund (1995).
4. M. Abrandt, Learning physiotheraphy: the impact of formal education and professional experience, *Linköpings Studies in Education and Psychology*, **50**, 1997.

5. J. Franz, L. Ferreira and T. B. Thambiratam, Using Phenomenography to understand student learning in civil engineering, *International Journal of Engineering Education*, **13**(1), 1997.
6. J. Karlsson, Studenters lärande och sammanhangets betydelse, (in Swedish). www.pedagog.lu.se/personal/jk/Studenterslarande.pdf, (2003).
7. D. Guerra-Zubiaga, H. Elizalde, C. I. Rivera, R. Moralesmenendez and R. Ramirez, Product life-cycle management tools and collaborative tools applied to an automotive case study, *International Journal of Engineering Education*, **24**(2), 1997, pp. 266–73.
8. L. Fink, S. Ambrose and D. Wheeler, Becoming a Professional Engineering Educator: A New Role for a New Era, *Journal of Engineering Education*, 2005.
9. E. De Graaff and H. P. Christiensen Editorial: Theme issues on active learning in engineering education, *European Journal of Engineering Education*, **29**(4), 2004, pp. 461–63.
10. J. Bernhard, Does active engagement curricula give long-lived conceptual understanding? In R. Pinto and S. Surinach (eds) Physics Teacher Education Beyond 2000, Elsevier, Paris, (2001), pp. 749–52.
11. M. Degerman, C.-J. Rundgren and J. Bernhard, The importance of using visualisations as an interactive tool in science education, ESERA2005, Barcelona, Spain, (2005).
12. A.-K. Carstensen, M. Degerman, M. González Sampayo and J. Bernhard, Labwork interaction—linking the object/event world to the theory/model world, PTEE2005, Brno, Czech Republic, (2005).
13. J. D. Anderson, *Fundamentals of Aerodynamics*, 2nd edn, McGraw-Hill, New-York, (1991).
14. D. R. Sokoloff and R. K. Thornton, Using interactive lecture demonstrations to create an active learning environment, *Physics Teacher*, 35, 1997.
15. J. Bernhard and O. Lindwall, *Approaching Discovery Learning*, ESERA2003, Nordwijkerhout, The Netherlands, (2003).
16. U. Engstrand, Particle Image Velocimetry (PIV)—Development of a low cost system (in Swedish), Master thesis, Linköpings universitet, Linköping, Sweden (2005).
17. A. Northedge, Rethinking teaching in the context of diversity, *Teaching in Higher Education*, **8**, 2003, pp. 17–32.
18. J. Biggs, *Teaching for Quality Learning at University*, Open University Press, Berkshire, UK, (2003).
19. S. Kolari and C. Savander-Ranne, Visualisation Promotes Apprehension and Comprehension, *International Journal of Engineering Education*, **20**(3), 2004, pp. 484–93.

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