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Active and Peer Learning in STEM Education Strategy

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ABSTRACT: Lifelong learning and diverse technical information are challenges for designing curricula. The Finnish National Defence University (NDU) provides undergraduate- and graduate-level courses in academic and military disciplines according to the Bologna process. Technology is one of the major learning lines at the NDU, but basic scientific education is also an essential part of the general curriculum. Elements of sustainable education strategy for STEM disciplines are discussed in this paper. Learning aims include gaining basic scientific knowledge, understanding how technology uses scientific results, and managing practical exercises within the work environment. This study presents only selected aspects, mainly those that may have a wider interest when teaching STEM subjects. Lecturing on fundamental topics is an effective method for using teacher resources for large study groups, while providing knowledge of the principles utilized in artefacts such as communication system devices. Exercises are an essential part of learning and are carried out in small groups led by peer assistants enrolled in the course. As a whole, when trying to enable better student motivation and learning results, enough space must be given for students' contributions.

KEY WORDS: STEM disciplines, sustainable education, education strategy

INTRODUCTION

Developments in science and technology are often claimed to produce a knowledge explosion. Likewise, demands to improve people's abilities to learn scientific knowledge, obtain new information, and resolve real-world problems are widely expressed. Furthermore, it is not enough for students to obtain professional knowledge, as in the future, they must be skilful workers with the ability to apply their knowledge and skills, even in new situations.

At the NDU, students must learn a comprehensive set of concepts covering many areas in physics and related disciplines. The target of education is that cadets understand the phenomena behind the applications. It is not feasible for cadets in the academic stage to study manuals for every machine or piece of equipment they will face in their working life. On the other hand, the practice to solve specific engineering

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problems is done by other personnel in the organization. Therefore, the leading aim in science and engineering education for cadets is to enhance their understanding of the essence of each phenomenon itself, even though the viewpoint may remain at a general level.

Formal knowledge levels and personal interests vary among cadets. In general courses (non-majors), the requirements are set for non-physics or non-mathematics majors. According to the curriculum and the semester plan, only compact and tightly scheduled science and technology courses are feasible.

Science, technology, engineering, and mathematics (STEM) education starts with a refresher type course in mathematics. Next, modelling or simulation activities are based on known rules that must be formulated in mathematical expressions. Equally, physics concepts or laws can be expressed as compact notes using mathematical formulations (Bing & Redish, 2009; Sherin, 2001). The next thing is to learn concepts and principles applied to any device that will be relevant in the cadets' future profession. The given information is based on knowing how to apply physics theories. Proper formulation with multiple real parameter consideration for accurate estimation with relevant calculations is beyond the scope. Here, a relatively limited lecturing frame must be adhered to by selecting only essential topics for lectures. To avoid browsing over less important themes in general textbooks, locally customized lecture material and textbooks are used and fine-tuned for each course.

Education laboratories or demonstrations are part of the practical professional science and technology courses, most of which is done in a later stage of education in the NDU, when cadets have already been divided according to their professional specialty. In this stage, the number and content of the demonstrations or work-related laboratory works are closely linked to the future work environment.

This study introduces topics and facets, which prove essential when enhancing student activity, creativity, and motivation at the NDU, which could help to achieve better learning outcomes. Action research type approaches and observations by lecturers are compared to learning outcomes to verify conclusions. While questions of student motivation in STEM subjects are universal, findings may give fresh ideas for a wider audience in the educational community.

HOW TO IMPROVE STUDENT ACTIVATION AND MOTIVATION?

Lectures: Are They Necessary?

Studies on exercise material often point out that increased use of exercises or demonstrations may improve students' understanding of new phenomena. In addition, visualization or practical demos are important, but deeper theoretical understanding of the phenomenon is often required when a learner is trying to understand the function or rules involved in the demonstration. This presents a challenge in finding the best method to teach theoretical aspects in a way that attracts interest and creativity. *Lectures that emphasize theory should be as interesting and attractive as practical demo sessions.* The importance of lectures is often undervalued. However, in many disciplines structured lectures form a solid basis for education, especially when teaching demanding and important concepts and phenomena to large study groups. Many active learning methods use well-structured lectures. Deep theoretical understanding improves cadets' ability to understand and sustain knowledge for learning practical applications. Sometimes, students lack the knowledge of fundamental concepts, and how they interact with each other, which causes difficulty in finding the path from the problem to the solution and finally reversing the path for consolidatory learning. Due to the formalities of officers' practice, even in science lectures obligatory presence prevails being also a local but useful choice to reach each student in the course. Pritchard (2010) presents the main aspects of lectures: communicating information, modelling problem-solving and reasoning, and motivating students. Motivation is important especially when teaching students (non-majors) in STEM subjects. Among students who are not majoring in technology, interest in STEM subjects or information describing fundamental structures is generally limited. When students are asked to read and produce their own remarks, quite often, deeper structural data or additional information does not provoke students to browse multiple pages or a wider set of sources. Thus, for better outcomes, most of the existing general material must be shortened, merged, or edited before being uploaded to the portal. In practice, dedicated links to the course's learning material or external sources with complementary commentary are more feasible.

Communicating Information: How to Intensify It?

What then are prerequisites for activating a deeper interest? In addition to the many ways to offer lectures that activate students, well-defined theory-based instruction should provide enough space for learners' creativity. *Pre-knowledge is needed* to prevent delivering information in a way that either exceeds the learner's knowledge level or is too simple and therefore boring (e.g., Rissanen, 2010b). In science and technology education in the NDU pre-assessment data, data and student feedback from previous courses and generalized data from successive years are used to adjust lecturing parameters. The STEM educational goal at the NDU is not aimed to represent the level for studying the discipline as a major in a typical science or engineering university following the Bologna principles. This issue is taken into account in educational planning. At the

NDU, general activating and motivating instructional methods are used. When delivering information to the audience, it is important to offer as much knowledge as necessary in structured packages that link to course-specific learning material sets. However, it is important to leave some of the responsibility to the students and cultivate creative approaches that support understanding and learner autonomy (Kahn, 2010).

At the NDU, question sessions and chat applications are used to improve cadets' creativity. Some ideas prove successful when trying to create motivating question sessions using informal questions. Without careful planning and scheduling, lectures are often implemented leaving only a brief period for students to ask questions. In practice, this means that only a few students are prepared and eager to use this opportunity to understand topics more comprehensively or to solve missing links from one concept to another. However, students prefer lecturers who provide opportunities to ask questions (Slomson, 2010). More engagement among students is gained when active communication takes place (e.g., Knight, 2003). When students learn that *there is a specific place and time for their questions, comments, and ideas,* they feel that their personal contributions are always welcome. This practice allows some delay from the pondering moment to the question-and-answer period, and is thus more relaxing for students. Students also have a chance to interact with each other when pondering these questions, ideas, or comments, which enhances their debating and reasoning abilities. If there are no questions or ideas, the lecturer may start the day's lecture or session by asking questions that are either answered immediately or later during the presentation. If a routine is implemented to convert undefined ponderings into structured questions, students may more successfully search for information anywhere at any time. There is also an opportunity to present questions or comments on portal pages, which are elaborated on in the next lecture. However, in addition to specific question sessions (Mutanen & Rissanen, 2012), questions are naturally accepted during lectures to improve the clarity of the message. All of this can be supported through the portal by delivering limited and structured information that supports a deeper understanding of the issues answered and discussed earlier. However, it is not always easy to express questions arising from one's thinking in terms of the discipline or as a common language. In this challenge, simple support questions are offered for cadets. For example, what are the aspects we do not understand? What are the aspects we should understand more comprehensively? Could we approach this phenomenon in another way? Sometimes the discussion is minimal or linked to the practical concern of, "how am I going to prepare for the upcoming examination?" For these problems, the inquiry technique or even a few minutes spent on a long pre-examination set may help.

Student Activation: Which Degree Is Optimal?

"*Much significant learning is acquired through doing*" (Rogers, 1969). Most homework or calculation exercises are carried out in small groups led by peer assistants currently enrolled in the course. Before starting STEM courses, students take a general pre-test, which evaluates their knowledge levels. The test evaluates comprehension level in mathematics (e.g., trigonometry and logarithm derivation), principles in physics, and practical calculation or estimation skills, without a calculator. Grading is straightforward: zero (an incorrect answer) or one point (a correct answer). This information serves educational planning in two ways. Those students who gain the best results have an opportunity to work as an exercise assistant in future courses. This information also provides cues for streamlining the lecture material for the upcoming course.

Students report that they have experienced peer assistant work as motivating and an extremely useful change of pace. For the other students, this practice has been welcome. This means that students have more space and responsibility in problem solving and reasoning through the exercise sessions, which also motivates students to get good grades. Typically, lecturers produce model answers. However, it is important that the peer assistants can also produce model sets and compare their own models to those the lecturer produces. When students have a more pronounced role in their educational process, they may be motivated to take a more active role in their future learning. This way "*shared responsibility means a potent force*" (Craft, 2013). With this peer approach, we promote a guided constructivist student-centred methodology (Clark, Kirschner, & Sweller, 2012), which helps students develop skills in the STEM area and form capabilities as team leaders. Leadership and scientific skills are not only useful to pass the course but also for the students' future professions. As an example of awards, at the NDU, cadets who earn the best grades have the right to choose among the first ones the orientation branch in their studies.

In the learning process, reaching a healthy balance in sharing responsibility is an important issue. Too much responsibility for students may result in a too slow and too heterogeneous learning level in a course. In demanding areas, this may also threaten the quality of the acquired knowledge level and discourage students. However, too complete learning entities without space for students' contributions may cause frustrations. Active students may feel that there is no place for their creative input at all, which makes them feel that their *creativity space* (Rissanen, 2010a) is too limited or useless. Passive students learn that their personal input in a theme or issue is useless or even disturbing, which may even increase their tendency to be only an evaluator. Due to the daily schedule and campus accommodation, cadets spend most of the week in close proximity to each other, which offers opportunities for peer support.

Therefore, when students start to ponder issues regarding learning subjects, they can form groups and find out answers to their questions as groups. However, it is also important to allow opportunities for individual problem solving, which some students prefer.

DISCUSSION AND CONCLUSIONS

Lectures have an emphasized and obligatory role in STEM education, which means that the lecture time allocation, methodology plans, and content design of lectures must be planned with care. Consideration must be given to how information can be communicated in a feasible manner, how problem solving and reasoning can be supported in a way that allows enough creativity space, and how students can be motivated appropriately. "*Independency, creativity, and self-reliance are facilitated when self-criticism and self-evaluation are basic and evaluation by others is of secondary importance*" (Rogers, 1969).

Students with a more pronounced role in their educational process exhibit higher levels of motivation to participate in their future learning, which may further motivate them to recognize the value of their personal input. However, estimating the amount of independence that causes a negative effect on learning outcomes is important (Clark et al, 2012). Therefore, areas suitable for independent learning must be selected carefully with the understanding that willingness to learn independently should be partially voluntary because of individual differences. With these prerequisites, autonomy without threats to the quality level is possible. "*Human beings have a natural potential for learning*" (Rogers, 1969); however, "*individual advancement is not the dominant driving force behind the creativity- communal development is equally important*" (Chappell, Craft, Rolfe, & Jobbins, 2012). When the learning environment supports students' natural creative potential in a constructive way, the learning targets become more reachable. However, "*humanizing creativity is about imaginatively developing new ideas which are valuable to the creators and their communities*" (Chappell et al., 2012). Hence, educational institutions must constantly self-evaluate their proceedings and have a readiness to change strategies, test new ideas, and regenerate.

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