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Students' SWOT analysis in mechanics of materials determines the action plans for students and instructor

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ABSTRACT: In this article, the authors refer to research performed to improve the learning of students in a course on mechanics of materials. When the course was taught in the classical way, the performance of the students was close to their performance in the three prerequisite courses. In the research undertaken, the authors evaluated the existing teaching conditions, considered a SWOT analysis for the students, which covered strengths, weaknesses, opportunities and threats, and then proceeded to the preparation of action plans for students and the instructor. The performance of students evaluated at the end of the semester proved to be superior compared to student performances from previous years.

INTRODUCTION

In this article, the authors refer to research that was accomplished to improve the performance of students in a basic engineering course called *Mechanics of Materials*. The course is taught in the traditional way, including lectures, examples, discussion, quizzes in the classroom and students solving homework problems and participating in three examinations. The performance of students was traditionally close to their performance in the three prerequisite courses, namely *Statics*, *Ordinary Differential Equations* and *Materials*.

The main task of this research was to evaluate existing conditions by assessing the strengths and weaknesses of students, as well as opportunities and threats, in connection to students' success in the course. The second task was to invite each student to create an action plan, while the third task was to encourage the instructor to reestablish his/her action plan regarding the procedures and policies of the course.

Educational philosophy helps instructors to answer questions, such as how should students be educated [1]. Experienced and concerned instructors assess the abilities of each student and then decide on an action plan, incorporating revisions to the regulations and policies of the course. As such, modifications can be carried out to better instruct their class and a larger number of students benefit from that instruction.

In the present research, the first task towards achieving students' learning was to assess the strengths and weaknesses of the students, as they themselves perceived them. The research procedure required that students carry out a SWOT analysis of themselves in relation to their success in the course and prepare their personal action plan. Students had to look at their strengths and weaknesses and describe those in writing and present the existing opportunities and threats to their success.

Research undertaken at *Schools Attuned* has helped teachers to better understand how the brain is wired, various ways that students learn, the patterns of student differences and how students can use their strengths to overcome their weaknesses [2]. For younger students, teachers volunteer to work on weaknesses; when one difficulty is surmounted, teachers can work on another. In higher education, students have enough experience to work alone on their weaknesses, occasionally with the help of other students and/or their instructor.

In the current research, the authors considered the procedures followed by the *Schools Attuned Approach for Instructors*, which is usually presented in training over five to six days, or weekend seminars during the school year. The procedures have included the following:

- Observing students' learning styles;
- Understanding students' strengths, weaknesses and affinities;
- Listening to students' talk about their weaknesses and learning difficulties;
- Building up students' strengths;
- Eliminating student's weaknesses.

The *Schools Attuned* programme is based on Dr Mel Levine's work at the Clinical Center for the Study of Development and Learning at the University of North Carolina, USA. Eight neuro-developmental constructs that have been found to affect learning include attention, language, memory, fine and gross motor skills, spatial ordering, temporal sequential ordering, higher order cognition and social cognition [3].

In this research, students were informed on the neuro-developmental constructs that affect learning, and were requested to assess individually their learning styles and personality type [4][5]. Further, the assumption was made that

students prioritise their needs in such a way that the success in specific courses is not their first priority. Differences in prioritisation cover sensitivities that were considered in evaluating the students' answers.

Research in the following areas can help instructors develop their action plans:

- Conceptualisation of student motivation [6];
- Motivation of hard-to-reach students [7];
- Academic motivation and the self [8];
- Motivation from an educational perspective [9].

Students at the university level have developed their reading and writing skills to reach a level of self-efficacy in cognitive development [10][11]. Research in the following areas refer to the development of the learner's abilities to the higher levels of cognition:

- Higher thinking system [3];
- Higher order cognition [12];
- Social cognitive theory and self-regulated learning [13];
- Complex cognition [14].

Research in education and improvement is an ongoing process [15]. Statistics on educational improvements are available [16].

The research described in this article evaluates the existing conditions of the course, considers a SWOT analysis for students in writing, and requests the preparation of action plans for students and the instructor. Students' performance and the display of their learning levels, as evaluated at the end of the semester, proved to be superior compared to performances from previous years.

STRUCTURE OF THE COURSE

The course titled *Mechanics of Materials* is a basic course in the civil and mechanical engineering programmes, taught during the first semesters of the engineering curriculum. Students are mostly young people with little learning experience in the university environment. The prerequisites for the course are *Statics*, *Introduction to Materials* and *Ordinary Differential Equations*, in which students are required to achieve grade C or higher.

The criteria for developing the guidelines for the course included the following main points, which were considered in developing the instructions (green-sheet) for the course:

- The title and the introductory sentence;
- Subject area and major topics;
- Summary of objectives for the instructor and students;
- Requirements on reading the theory and practicing problems;
- Required textbook, suggested literature and handouts;
- Grading system and examination policy;
- Class schedule with dates for the lectures, homework due and examinations.

Mechanics of Materials is the application of science to analyse the behaviour of structural and machine elements for stress and deformation under loads. The course is a three-unit course and the class meets twice a week for 75 minutes each time. Mechanics of Materials is the prerequisite course for structural design courses (concrete structures, steel structures, timber structures). The required textbook was *Mechanics of Materials* by Hibbeler [17].

The course objectives are to teach the students on how to apply the basic analysis techniques for determining stresses, strains and deformations in structural and machine elements under axial, torsion, bending loads, plus combinations thereof.

The topics of the course include chapters with lectures on stress, strain, mechanical properties of materials, axial loads, torsion, bending, transverse shear, combined loadings, stress transformation, strain transformation, design of beams and shafts, buckling of columns and energy methods.

The objectives of the course, regarding the goals for students' learning associated with the topics or content of the course, correspond to the 13 chapters of the textbook and require that the students are able to:

- Understand the concept of stress;
- Understand the concept of strain;
- Explain the mechanical properties of materials;
- Calculate stresses of axial loads;
- Calculate stresses of torsion;
- Calculate stresses of bending;
- Calculate stresses of transverse shear;
- Compute stresses and strains for combined loadings;
- Perform stress transformation;
- Perform strain transformation;
- Perform design of beams and shafts;
- Calculate dimensions of columns due to buckling;
- Understand the concepts of energy methods.

Evaluation of the learning of students is undertaken mainly by testing the students at several intervals: the first mid-term examination after Chapter 6, the second mid-term examination after Chapter 11, and the final examination after Chapter 13. Also, quizzes and homework turned in weekly contribute in testing the students' performance.

Grades were distributed as follows: 30% for the final examination, 25% for each of the two mid-term examinations, and 20% for homework and quizzes. The class policy required that late homework not be credited. Quizzes announced or unannounced were part of the homework. Examinations were closed book and closed notes.

RESEARCH PROCEDURE

The research procedure included three tasks, as follows:

- The first task was to assess the existing conditions, mainly students' strengths and weaknesses;
- The second task was to ask each student to create an action plan;
- The third task was to encourage the instructor to reestablish his/her action plan regarding the procedures and policies of the course.

Methods to process and analyse educational data collected in the classroom were developed for qualitative and quantitative data, either as simple or mixed approaches [18]. The design of data collection in the present research was simplified by distributing to students a blank page on which they had to write

their strengths and weaknesses, and the opportunities and threats (SWOT analysis).

SWOT analysis is a technique utilised in business to help a company state its strengths and weaknesses, assess the opportunities and threats of the business environment in which the company operates, and create an action plan for future activities.

Transferring this technique into the classroom, students are asked to identify personally their strengths and weaknesses for the specific course, to evaluate the opportunities and threats of the environment around them regarding the external factors of their success, and using the combined knowledge thereof to prepare an action plan for their success in the course.

The survey regarding the SWOT analysis was given to the class twice, first after the fifth week of the semester, and then after the twelfth week, in a 15-week semester. Students had to write down those items that were mostly expressing themselves.

After finishing the SWOT analysis, students were asked to think about their previous successes and about other students who were successful in their engineering studies. Students were then asked to discuss or share ideas in small groups in the classroom and provide success stories regarding activities and procedures that, if followed, would definitely help them to develop competences that would lead them to final success.

Questions on how to explore and find opportunities, and on how to reduce or eliminate threats, was something that students were asked to think about, and indicate to their instructor what environments gave opportunities to students and what would eliminate threats towards their success in the course.

Students were asked in their small groups to write down lists with strengths, weaknesses, opportunities and threats associated with their final success in the course. Then, they had to separate all columns in sets of personal, academic, career, social, economic items. Within each set, they then had to prioritise items in sequences of importance. Each group had to compare their lists with lists from other groups.

The groups continued with their action plans, with specific activities for each student, that included the steps each one had to take in using his/her strengths, eliminating weaknesses, taking advantage of opportunities and avoiding threats.

By evaluating students' responses from an auxiliary questionnaire, the instructor could come up with general comments regarding the background and behaviour of students in the class. The results are as follows:

- More than a quarter of the students had very strong backgrounds in mathematics, statics and materials;
- More than half of the students knew well other students in the class;
- More than one third of the students were ready to collaborate with their classmates;
- Almost all the students considered the educational procedures and guidelines firmly stated and not flexible;
- Almost all the students considered the final examination (comprehensive) as the greatest threat to their success in the course.

RESEARCH RESULTS

The answers of the students concerning their strengths and weaknesses, opportunities and threats regarding their success to the course, were reviewed, summarised and organised into certain main items, which are listed in Table 1. The same table displays the frequency of answers, considering the 35 students in the class. The frequency is shown as fraction of 1.00, where 1.00 means that all the students indicated concern on the same item.

At the university level, students knew that they had to develop their own action plans if they wanted to enhance their learning, succeed in the courses they were taking, decrease their anxiety and frustration levels, and maintain their motivation and self-esteem or pride. Although students prepared and revised action plans continuously during their university studies, this was the first time that they had to work on their plan in class with the help of their classmates and the instructor.

Based on the results of the SWOT analysis shown in Table 1, the instructor could then develop a list of measures that would help in developing a positive and trusting relationship in the classroom, a safe, positive and supportive environment, and mutual respect of students and instructor. Also, strengths and weaknesses of students that trigger certain behaviours should also be included. Caring and observing instructors make a difference to the success of their students. The same also happens when students observe and care for their instructors.

ACTION PLANS

The research procedures included as second and third tasks the creation of action plans from the students and the instructor. In order to create action plans, information from the SWOT analyses was used to provide the following:

- Evidence that students' personal strengths would favour their success;
- Evidence that students' personal weaknesses would not impede students' learning;
- Assurance that the procedures followed and the measures taken would assist students' learning and create opportunities for them;
- Assurance that revisions and changes to the course regulations should eliminate the threats to students' success.

Students, in developing their action plan, considered individual answers to the items of Table 1 regarding strengths and weaknesses. Students also requested a quick repetition of the material of the prerequisite courses at the beginning of the semester to refresh their skills. Experience from research to improve the performance of students in a required core course in computing showed that a voluntary review seminar in the first week of the semester proved to be advantageous for those students who took the course [19]. This activity might be useful in developing the strengths of students and eliminating their weaknesses at the beginning of the semester.

Students also considered in their action plan the use of programming languages, which would be challenging but would still facilitate their computing efforts. Undergraduate engineering programmes were surveyed to determine the usage of programming languages (C or FORTRAN) versus the use of

computational software systems (*Matlab* or *MathCAD*); this indicated that three-quarters of respondents required a programming language [20].

In their action plan, students considered requesting a non-traditional instructor-led course, a Web-assisted course, a streaming media course, or an interactive video course. Research performed using modern technology in a statics course with a common syllabus, homework, tests and grading system indicated that instructional technology improved student's performance [21]. Also, problem solving courseware modules developed for students enrolled in the Mechanics of Materials course at the Department of Mechanical Engineering, Carnegie Mellon University, indicated a better grasp of fundamental principles, a sense of the meaning of key quantities, and fluency to use relations to solve problems [22].

Students also considered using the Internet in their action plan. Research performed in a structural timber design course, which provided supplemental modules on the Web, indicated that the Internet augments student learning, comprehension and retention of material [23]. However, there is the question as to whether critical thinking is promoted, although it definitely assisted students with a variety of learning styles.

Instructors, in developing their action plan, might consider using current pedagogic research findings when designing and delivering courses [15]. The action plan that the instructors should consider when performing SWOT analysis in their courses has the characteristics shown in Table 2.

In a study of bridging courses, the researchers indicated that the bridging had a systematic influence on performance and attitudes for the students; they also identified the principal components of an action plan [24]. These components are extended here into the following tasks of an action plan for instructors:

- Clarify concepts and pinpoint possible confusion of students in style, terminology, notation, and differences in approach;
- Identify the main concepts and indicate the engineering importance of the material to students;
- Introduce contextual learning and engage the concepts of the prerequisite courses into the terms of the present course;
- Communicate with the instructors of prerequisite courses so as to create connections between the instructors and disciplines;
- Invite a guest lecturer to incorporate credibility and authority into the course material.

From the point of view of the instructor's action plan, the Internet was not introduced, primarily because of adverse effects to students' exposure to the concepts and practicing critical thinking. However, students were encouraged to program the solutions of their problems, control the accuracy of their results, organise solutions for similar problems, and develop alternative solutions to certain problems by using programming languages.

STUDENTS' SUCCESSES

The criteria for evaluating the performance of students were at different levels for the content of each chapter. Students had to demonstrate knowledge by solving problems relevant to each chapter, and answer correctly 4-6 questions in each problem. A grade was given according to the displayed knowledge of the concept and formulae, execution of the calculations without errors, deriving the correct answers and plotting shear force and bending moment diagrams.

The instructor should suggest to students methods to improve their learning in an area and make it easily understood. The learning area was presented and then suggestions regarding the items listed below were considered for improvement:

- Classroom environment and educational means;
- Classroom size and group sizes;
- Instruction time utilised wisely in lecture, practice, discussion and conclusions;
- Instruction method according to established students' learning styles;
- Repetition of parts of the instruction for clarification.

Students' successes were measured using their performance in the course, according to the grading system considered, for a series of checkpoints along the learning process. The monitored grades of students were for class participation (quizzes and class practice), homework problems, mid-terms and final examinations, and the total grade were placed in increasing order and plotted. The respective graph is shown in Figure 1.

Comparing the performance of students for the course of Mechanics of Materials to the courses they undertook as prerequisites, one can observe an improvement in performance of the type of a linear equation (first order polynomial) with formula $y = 0.80x + 15$, where x (independent variable) is the average grade obtained in the prerequisites and y (dependent variable) is the grade obtained in the Mechanics of Materials course. This improvement was not obvious in previous semesters, where a formula of the type $y = x$ was mostly valid. The formula of the linear equation (first order polynomial) is closest to the equation of the trend-line of the total grade, as shown in Figure 2, and is especially valid for the two mid-terms and the final examination with an insignificant error. More specifically, Figure 2 shows that mid-term 1 was graded higher, while mid-term 2 was graded lower, and the final test was graded approximately close to the total of the three tests.

The instructor usually does not know, or else is not sure, as to whether students understand and learn the material until they are tested. Then the instructor can decide to re-mediate one or two students or re-teach the entire chapter. Students also are not sure if they get something right or wrong, to decide if they need more study or if they can proceed to the next subject. However, the results of this research are encouraging, indicating student learning improvements if a SWOT analysis is performed and action plans are prepared for students and the instructor.

The assessment of each student separately regarding the strengths and weaknesses is difficult and time consuming in large classes. The development of computer software, incorporating standardised tests and yielding scores with a breakdown of students' abilities should be helpful, for example in grouping those students who are strong in mathematics but weak in problem solving. The instructor can then formulate the lecture accordingly in order to teach groups of students during office hours in a way to develop their missing abilities; this technique was actually employed in the current teaching of the Mechanics of Materials course.

DISCUSSION

From the perspective of students, they always look at their strengths and try to improve them, and know their weaknesses and try to eliminate them. In their educational goals, students not only complete the requirements of a degree programme but also work on their weaknesses.

The learning abilities of a student entails a collection of personal characteristics, such as strengths and weaknesses, on how individuals receive, store and process information. Different factors affect learning styles, including environmental and instructional preferences, personality issues on interpreting information, mental processing models and cognitive abilities.

Students should develop their own learning strategies so as to utilise their strengths and compensate for their weaknesses. Students should know their learning styles, become more aware of their thinking processes and, when conscious of learning style differences, develop interpersonal communication skills that are critical to their success, especially as adults.

From the perspective of instructors, they have a sense of who they are as persons and professionals; they come from different cultures with strengths and weaknesses, and likes and dislikes. In the engineering field, instructors are often professionals with research, design and construction experience, or managerial and consulting experiences, while sometimes lacking pedagogical talents.

When significant differences exist between teaching and learning styles that have not been addressed, students become inattentive, uninterested in the course, and low performing. At this point, instructors should teach students to have flexibility in their learning styles and learn under different teaching styles. Instructors should also display flexibility in their teaching by addressing the different learning styles of the students.

The instructor's evaluation of students' learning abilities does not refer to the quantity of right and wrong answers, while deeper and sensitive observations are needed, such as:

- Patterns of errors due to missing knowledge on assumptions and procedures;
- Erroneous performance of certain tasks by the student for a sequence or procedure;
- Consistent incorrect application and evaluation of theory;
- Difficulty and non-fluency in the assimilation of new knowledge;
- Reactions to conditions that affect the student, plus reactions to procedures or strategies.

The action plan for each student will be associated to the vision, mission, core values and priorities that each student has. At the university level, instructors and departments are interested to increase student success by strengthening student teaching and learning, by providing academic quality, by monitoring student development and success, by providing easily accessible and affordable education, and by controlling resources regarding efficiency and effectiveness.

Regarding opportunities and threats, there is a range of environmental factors in the classroom and students' behaviours when they interact with instructors, other students, or face problems with the curriculum. By observing students' behaviour and analysing performance expectations, it is possible for the instructor to determine the individual patterns of students' strengths and weaknesses and be able to deal with the problems.

The difficulties that students face and the different performance patterns refer to the following:

- The classroom environment, the instructor's personality, and students' likes and dislikes;
- The context and format of the course (ie textbook, homework problems, teaching style, examinations, etc);
- The demands of student tasks (eg quizzes, homework, examinations, etc) regarding available time, organisational skills, rates of performance, memory and ingenuity.

In addressing weaknesses, especially when solving problems, students are usually unable to classify problems by considering superficial features [25][26]. By applying a repetition of similar problems, they become able to understand the basic principles. If different types of problems and their respective solutions are given, then students memorise one method for each problem [27].

Regarding low levels of commitment and low motivation of students, the instructor may follow the example of McMaster University in organising workshops to help students address low self-image and high short-term and long-term anxiety [28].

CONCLUSIONS

In this article, the authors refer to research performed to improve the success of students in the basic engineering course of Mechanics of Materials. The course is taught in the classical way, which includes lectures, class participation, quizzes, homework problems and examinations. The performance of students was traditionally close to their performance in the three prerequisite courses.

The research undertaken was organised in three steps: an evaluation of the existing conditions by considering a SWOT analysis for students, preparation of action plans for students and an action plan for the instructor. The performance of students evaluated at the end of the semester proved to be superior compared to performances from previous years. The success of these students was attributed to the facts that students utilised their strengths and addressed their weaknesses, while the instructor created opportunities and eliminated threats for students during the semester.

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