Active Learning for Applied Strength of Materials Course: Evidence From NTTU

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***Abstract*— In the process of teaching Strength of materials, students often find it difficult to understand and the level of achievement of the course learning outcomes is not high. Therefore, active teaching methods and application of computer aim to support students actively, proactively, and in project-based learning. This article presents the possibility of integrating the Mdsolids software in teaching strength of materials at Nguyen Tat Thanh University (NTTU) for students majoring in automotive engineering technology. The student satisfaction survey on the course and the application of Mdsolids in teaching were conducted and evaluated to test the effectiveness of active learning activities. The obtained results confirmed further evidence of the benefits of Mdsolids in supporting students to achieve the course learning outcomes.**

Index Terms*— *active learning, mechanics of materials, Mdsolids

I. Introduction

The strength of materials is a core subject for students in the mechanical engineering technology. The main topics taught are design and analysis of structural elements subjected to tension, compression, torsion, bending and buckling, bolt joints, including the basic concepts of stress and strain. In the process of teaching this course, students often find it difficult to understand and the course learning outcomes are not achieved. Therefore, active teaching methods and application of computer motivate students in learning process. This subject is the most important subject to support the next subjects such as machine design, mechanical design project, thesis report, etc.

With the purpose of good support for students, the article tries to show how to apply Mdsolids software to teaching strength of materials, solve common exercises in mechanical engineering technology, help students to develop practical problem-solving skills; thereby, encouraging students to have the spirit of self-study and develop a design thinking..

II. Related Works

Today, technical education can be seen as realizing the potential of multimedia as a learning and teaching tool. The use of computer provides several useful tools in mechanical engineering education. Classic technical graphics topics using a combination of animation, audio descriptions, and interactive exercises can help students. The most important benefit provided by multimedia can be considered as interoperability. Many studies showed that interacting with information can have a positive effect on learning because people remember/absorb more information if they interact with it (e.g., hearing, seeing, and doing). Multimedia provides an excellent means of creating interaction through interfaces that require the user to make choices and perform actions. The integration of information technology in the applied educational activities of mechanical and automotive engineering technology, provides an excellent opportunity to increase the student's level of understanding with specific pedagogical resources during the teaching process, especially teaching the fundamental engineering disciplines such as Machinery design, Mechanics of materials, and Mechanical Vibration, in an interdisciplinary classroom-laboratory [1].
The project assignment effectively fostered collaboration and active learning. Since the project assignments closely resemble text problems, students need to spend more time reading and understanding. After overcoming the initial hurdle of mastering the fundamentals of software tools, students can easily create models corresponding to assigned problems and change important parameters to set up different situations. To establish correspondence between the software solution and the analytical solution for these different situations, the students have moved more into an “active-active learning” framework from a the more “passive learning” model they are used to. The software was made available on all computers in the computer facility and allowed students to work on their own time. Stronger students who quickly master the software not only demonstrate an enhanced understanding of the subject, but also help their teammates in some personal misconceptions. During the project presentation, students are encouraged to ask questions to learn from other groups about their approach and seek clarification of concepts where appropriate. The project

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assignment also promotes better use of faculty hours by some (unfortunately not all) students who are really excited about the software simulations and correspondence with the solutions from analytical method. Some students also put extra effort into software mastery and spend more time on and off course requirements when they realize that simulation environment is also suitable for Mechanics of Materials courses to follow up and use for project assignments in these courses [2].

Setuju and Suparmin [3] determined the effectiveness of using Mdsolids software to improve academic performance and academic independence of students at the University of Sarjanawiyata Tamansiswa Mechanical Engineering Education Yogyakarta. They performed with a semi-empirical method. The results of the study were collected with the experimental group and analyzed by the t-test. The independence of students' learning during class time is observed and further analyzed by calculating the achieved scores. The results of the t-test of the difference test provide information that the average performance of the experimental group is significantly different from that of the controlled class. Students who used the Mdsolids software in the mechanics of materials course after observing an increase in learning and independent learning at the end of each course with good grades.

In preparing future engineers and scientists, universities are faced with the challenge of gradually teaching students the realities of modern mechanical engineering technology, namely the mechanics of occurs from the interaction between different parts of complex engineering systems. The use of the Internet in the classroom offers the opportunity to effectively apply advanced learning methodologies and systems that can help students broaden their horizons and discover new knowledge. Alic, Miklos and Miklos [4] described the experience of using specialized software (over the Internet), for interactive and collaborative learning in mechanical engineering. In mechanical engineering education, the concepts developed in the engineering mechanics course, which are essential in preparation for design courses in engineering technology disciplines, provided the designer with the tools needed to select a suitable material and establish the required dimensions for the machines and mechanisms. They also assert that for students, the key to success in the course is to develop engineering problem-solving skills by solving several problems that are derived from a variety of mechanical and structural situations in the context of mechanical engineering education.

Active learning enhances technical education. Linsey, Talley, White, Jensen and Wood [5] presented the rationale, curriculum supplements, and approaches to active learning that can be seamlessly incorporated into a lesson-based engineering classroom traditional teaching. An educational theoretical framework that structures active learning experiences and includes consideration of the learning styles and preferences discussed. They presented innovative activities for engineering mechanics courses designed to meet the diverse needs and diverse learning styles of students.

A laboratory-oriented course was created to supplement lecture instruction on statics and strength of materials [6]. The primary goal at the start of the course is to provide students with more problem-solving experience with the secondary objective of hands-on experience building intuition. More than 25 activities have been developed with limited budget. The richness provided by the course, both in terms of physics examples, additional problems and time taken, clearly provided students with additional involvement in this difficult subject. This experience also brings the faculty closer to the students. Working Model 2D is a powerful, easy-to-use flat multi-body software that has been adopted by many Statics, Dynamics, Mechanics, Machine Design instructors as well as practicing engineers. The programmability and import and export capabilities of Working Model 2D facilitate the motion simulation of complex shaped objects subject to multiple constraints. Simionescu [7] presented several its applications that will be described allowing students to understand the basic properties of gears and how they are fabricated. Other applications allow students to study the kinematics of planetary gears, which are known to be less intuitive than those of fixed-shaft gearboxes. This helps inspire students in the process of active learning and independent problem solving.

Most of the first-year engineering students at the University take Calculus as their first math subject. This course aims to acquaint new students with the University, reinforce mathematical concepts and introduce diverse areas of engineering. Interactive computer simulations have been created using the Working Model 2D and MDSolids modeling programs to introduce and reinforce topics and skills related to the four engineering majors (Civil, Electrical, Electrical, Material Science and Mechanical Engineering) offered at the university. Guarino, Callahan, Chyung, Walters and Clement [8] indicated that students enjoy using simulations and consider them interesting additions to learning. Students also felt that the simulations have improved their confidence to take engineering courses in the future and are ready to use more simulations in their academic careers. There was no significant correlation between students' dominant learning styles and their perception of the simulations. Therefore, scores based on learning styles may not be needed to effectively use simulations in similar learning environments. MdSolids is the current educational software for the mechanical course usually presented as a tutorial, sheet, or basic analysis package. The new software package MDSolids, presents an alternative to product categories in engineering education in mechanics. MDSolids was conceived as a tool to help students solve and understand homework assignments, commonly used in a materials mechanics course. The software is flexible, graphical, informative, and very easy to use. MDSolids is being used in several schools around the world, and user feedback has been positive and enthusiastic [9]. MDSolids is educational software primarily intended for students in the Mechanics of Materials course. MDSolids has been freely available to the engineering education community since 1997 and it has been made available to hundreds of schools and universities around the world. Although MDSolids has been widely used, there has not been a formal study of its role in Mechanics of Materials education. To collect information about the use of the software, a survey was conducted to collect information on (1) the type of learners using MDSolids, (2) the students' attitudes about using the software, (3) information on how professors use MDSolids in their teaching, and (4) the effect of MDSolids on student achievement in selected topics as perceived by professors. Survey results showed that MDSolids are used in all kinds of settings in a variety of ways. The professors noted that MDSolids served to help motivate

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students and it appeared to be a factor in the notable improvement in student performance outcomes in several subject areas [10].

Stites, Krousgrill, Rhoads, Berger, DeBoer and Goldenstein [11] described the development of a set of active learning activities for an undergraduate course in materials mechanics. One of the main motivations for creating and implementing new activities stems from the physical space in which the course is taught - a classroom specifically designed to encourage collaboration. Round tables in the room and whiteboard-lined walls inspired a veteran, a mechanical engineering instructor, and a graduate student in engineering education to design a range of learning activities. Active training for the mechanical engineering industry. The objectives of these activities are twofold: 1) to enhance cooperation among students during lectures and 2) to enhance students' conceptual understanding of difficult but still relevant topics. Preliminary results indicated that the students found the activities helpful for their learning and were comfortable with the target concepts. This working manuscript briefly described each active learning activity and illustrated the pedagogical benefits of cross-departmental collaboration. They detail six active learning exercises that are the result of a cross-departmental effort to increase the frequency of collaboration in the collegiate mechanical materials class. The students reported that all activities were helpful in assisting them to learn related concepts. Furthermore, preliminary results from qualitative data suggested that students benefit from collaborating with peers. Because of the obvious technical and social success of these activities, the instructor plans to include these activities in the curriculum. The need to provide more “student-centered” instruction in higher education while improving retention has created the need to provide students with more flexible help outside of the classroom setting and deeper challenge is how to do this in the reality of tight budgets. Richter [12] described how Eastern Washington University has chosen to meet this challenge in the field of teaching Strength of Materials. Eastern Washington University decided to use a software package to allow students to have more "on-demand" help in solving problems in the mechanics of materials. The software package allows students to work through problems then use the software to examine their work, helping to understand where could go wrong and providing an environment that encourages further inquiry and discovery. The experience and lessons learned in using the software "MDSolids" to enhance the effectiveness of traditional classroom learning experience.

Sutherland [13] has developed an undergraduate course to introduce students to the fundamentals of automotive dynamics. Many students, although they are genuinely interested in the subject, have difficulty grasping the principles of physics necessary to have a complete understanding of the subject to support their aspirations and in making informed vehicle design decisions. A fascinating fact that is potentially useful is that the world of computer games has extensively developed very sophisticated vehicle computer models with realistic driver interfaces. However, while be very enjoyable, these computer games are not suitable for helping undergraduate engineering students and understand the fundamentals required for car design. Therefore, as part of this course, students develop their own dynamic models of the vehicle (using Working Model 2D) starting with the vehicle's simple suspension and operating the four-wheel drive vehicle. on rough road. The innovation from a teaching point of view is that students can gain a clear understanding of some three-dimensional effects, and thus design principles derived from this understanding, with a simple program, and use available 2D dynamics simulation software. This supports students to learn, actively and creatively in the design and problem solving of vehicle/car dynamics and dynamics.

III. Teaching Content and Methods

The subject “strength of materials” provides knowledge about stress, strain, and the relationship between them. The bars are subjected to tension – compression, bending, and torsion. Theory of internal forces and methods of drawing the internal force diagrams. Complex load bearing bar problems such as pure bending, bending plus tensile and compression, bending plus torsion, etc. Methods of calculating strength, stiffness, and stability of machine parts subjected to various forms basic deformation. After completing this course, students will be able to: (1) Analyze and build appropriate computational models for mechanical parts when subjected to shear, internal forces generated in tension, compression and torsion, subjected to bending force acting on any mechanical system, determining the equilibrium condition, and the internal force components on the cross-section; (2) Apply basic knowledge of the subject to calculate the applied forces, draw and interpret internal force diagrams; (3) Calculate the stress at a point on the cross-section of the bar under tension and compression, torsion, shear and flexural bars, draw the distribution rules of stress components on the cross-section; (4) Build skills in analyzing the forces acting on the object, thereby identifying defects or failures on the part, finding solutions based on the learned knowledge to solve problems with practical topics in a creative and appropriate way to meet the requirements in the field of automotive engineering technology.

The course content and illustration of problems through Mdsolids software are presented in Table 1.

IV. Survey Results

The questionnaire is designed to survey student satisfaction about the subject of strength of materials. The questions are designed to follow the teaching activities, evaluate the lecturers, and evaluate the students on the level of achievement of the course learning outcomes. The results of the survey were conducted among 100 students with the levels as follows: 1. Very dissatisfied 2. Unsatisfied 3. Temporarily Satisfied/Normal 4. Satisfied 5. Very Satisfied.

The criteria for evaluating are described as below:

- Teachers stimulate students' interest in this subject (level 3: 2.2%, level 4: 24.7%, and level 5: 65.2%).
- Teachers observe and manage learning activities, and the speed of teaching and learning in class is good (level 3: 3.4%, level 4: 25.8%, and level 5: 64%).
- The teacher organized and prepared well for each lesson (level 3: 3.4%, level 4: 22.5%, and level 5: 69.7%).
- Teachers encourage discussions and answer questions during class (level 3: 4.5%, level 4: 27%, and level 5: 61.8%).

- Teachers encourage independent and creative thinking of students (level 3: 4.5%, level 4: 20.2%, and level 5: 68.5%).
- Teachers demonstrate in-depth knowledge of the subject (level 3: 3.4%, level 4: 21.3%, and level 5: 68.5%).
- The teacher showed enthusiasm and interest in the lesson (level 3: 2.2%, level 4: 19.1%, and level 5: 71.9%).
- Teachers used many teaching methods to achieve the objectives of the subject (for example, group discussions, presentations, students' homework, class assignments, etc.) (level 3: 3.4%, level 4: 22.5%, and level 5: 66.3%).
- The lecturer challenged the students to complete the lessons and exercises the best (Level 3: 4.5%, Level 4: 23.6%, and Level 5: 65.2%).
- Teachers illustrated a relationship between theory and practice in their lectures (level 3: 3.4%, level 4: 22.5%, and level 5: 66.3%).
- Teachers provide useful, constructive feedback, especially through lessons and assignments (level 3: 2.2%, level 4: 22.5%, and level 5: 67.4%).
- The teacher clearly explains the content of the subject (level 3: 2.2%, level 4: 22.5%, and level 5: 68.5%).
- Teachers are ready to provide personal help for students to complete the course in the best way (Level 3: 2.2%, Level 4: 22.5%, and Level 5: 68.5%).
- Teachers care about students' progress (Level 3: 4.5%, Level 4: 22.5%, and Level 5: 65.2%).
- Teachers can be outside the classroom by teaching online (level 3: 4.5%, level 4: 23.6%, and level 5: 62.9%).
- Teachers have been active and trying to prevent cheating in this subject (Level 3: 5.6%, Level 4: 21.3%, and Level 5: 66.3%).
- Teachers make good use of information technology devices to support teaching (level 3: 2.2%, level 4: 20.2%, and level 5: 70.8%).
- Information on assessment, testing, and end-of-course exams is clearly communicated (level 3: 3.4%, level 4: 27%, and level 5: 62.9%).
- Students' learning results are assessed accurately, objectively, and fairly (level 3: 4.5%, level 4: 24.7%, and level 5: 64%).
- The exam questions are closed to the curriculum (level 3: 9%, level 4: 24.7%, and level 5: 59.6%).
- Teacher feedback is provided within the stated timeframe (level 3: 4.5%, level 4: 23.6%, and level 5: 65.2%).
- Feedback shows how to improve your learning (e.g., Correction of assignments and other comments) (level 3: 4.5%, level 4: 25.8%, and level 5: 62.9%).
- The duration (number of periods) for the subject is appropriate (level 3: 5.6%, level 4: 22.5%, and level 5: 64%).
- The library has enough reference materials for the subject (level 3: 14.6%, level 4: 28.1%, and level 5: 51.7%).
- Teacher guides on where to find documents (level 3: 7.9%, level 4: 25.8%, and level 5: 61.8%).
- The equipment in the classroom meets the teaching and learning requirements (level 3: 10.1%, level 4: 23.6%, and level 5: 59.6%).
- The outline was introduced and explained at the beginning of the course; The course was delivered as outlined in the outline; Great assignments/exercises related to the learning outcomes and learning outcomes of the subject: 98.9% students agreed.
- The teacher explains the grading criteria of the subject; This is a subject worth learning: 97.8% students agreed.
- Exams/tests related to the course learning outcomes: 100% students agreed.
- Would you/students/learners recommend this course to future students? 95.5% students agreed.
- You/students/learners contributed to lesson development and class activities (level 3: 20.2%, level 4: 27%, level 5: 44.9%).
- You/students/learners feel that you are achieving your academic results and course learning outcomes (level 3: 13.5%, level 4: 32.6%, and level 5 47.2%).

Overall, how would you rate your experience in this subject? The answer is depicted in Figure 1.

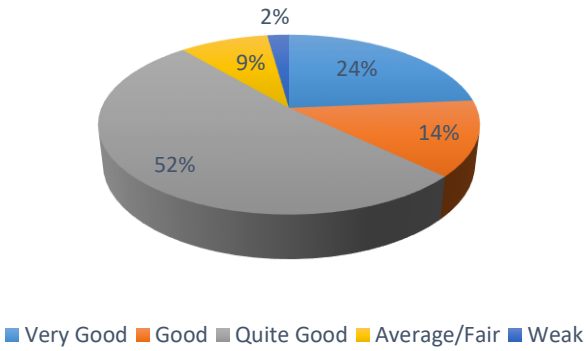


Fig. 1. Students' Experience in the Strength of Materials.

How many hours a week do you prepare, do homework for the subject? The answer is depicted in Figure 2.

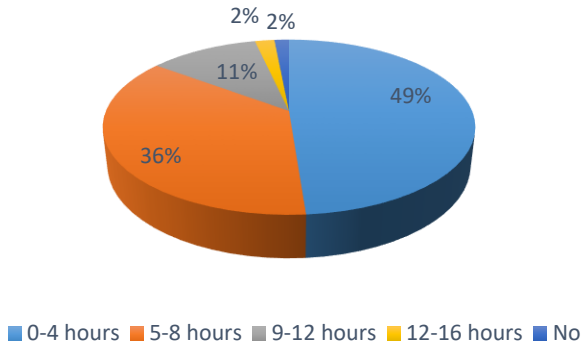


Fig. 2. Students' Workload Per-week on the Course.

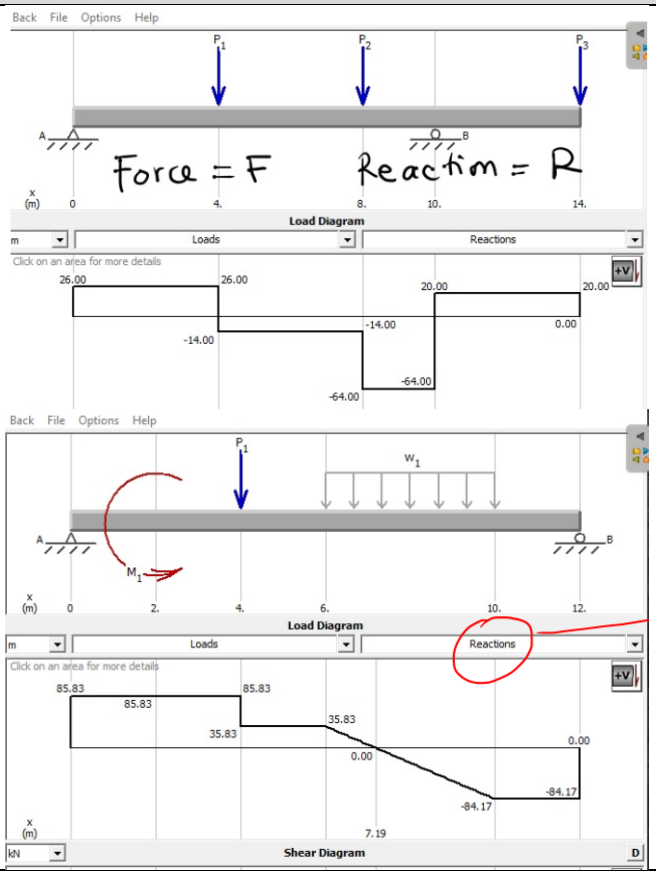
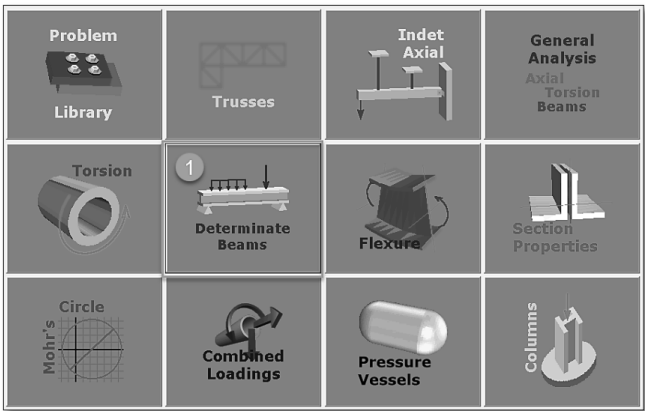
V. CONCLUSION

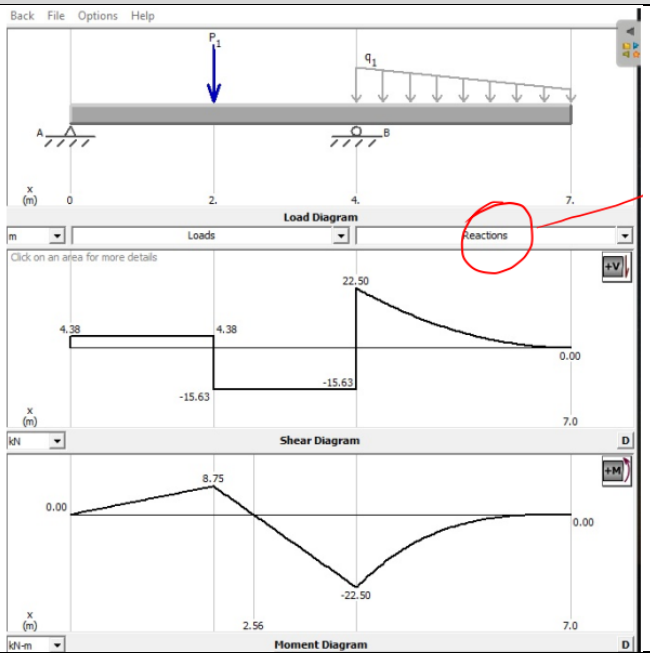
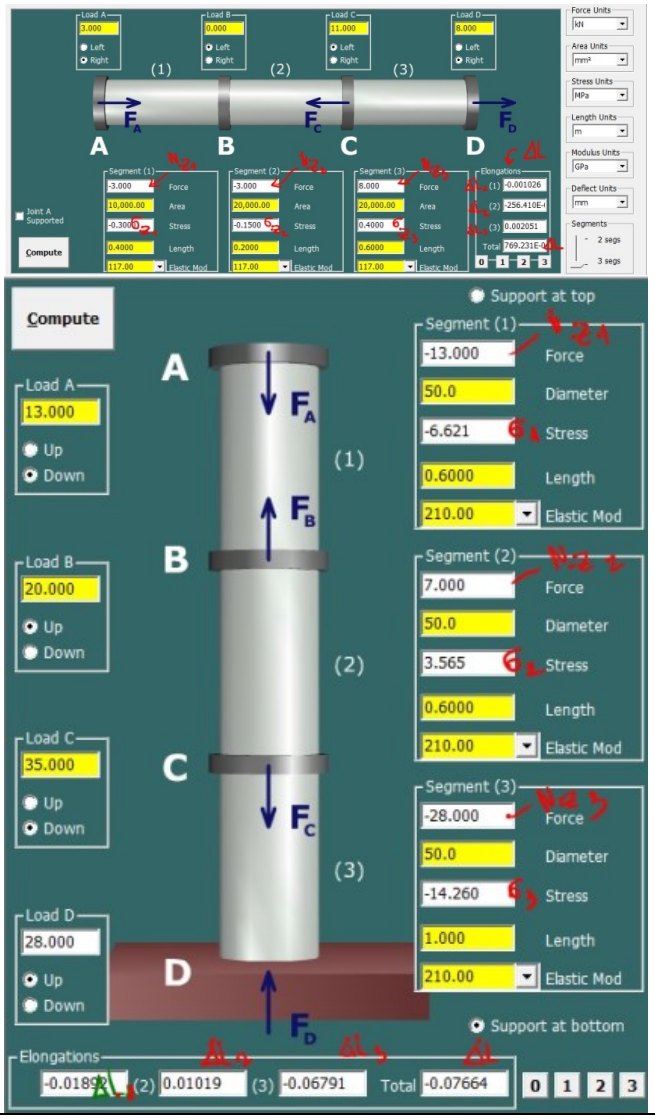
Strength of materials is a difficult subject, and it is difficult for students to achieve the course learning outcomes. This paper presented the evidence from NTTU in applying Mdsolids for active teaching and learning. Mdsolids proved the effectiveness and value for students in the process of self-

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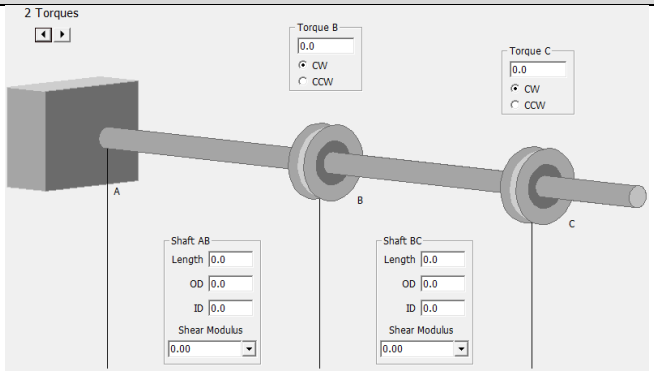
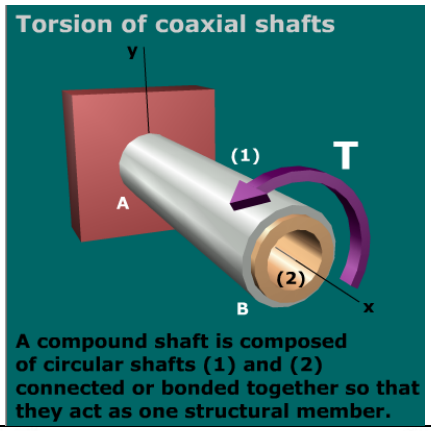
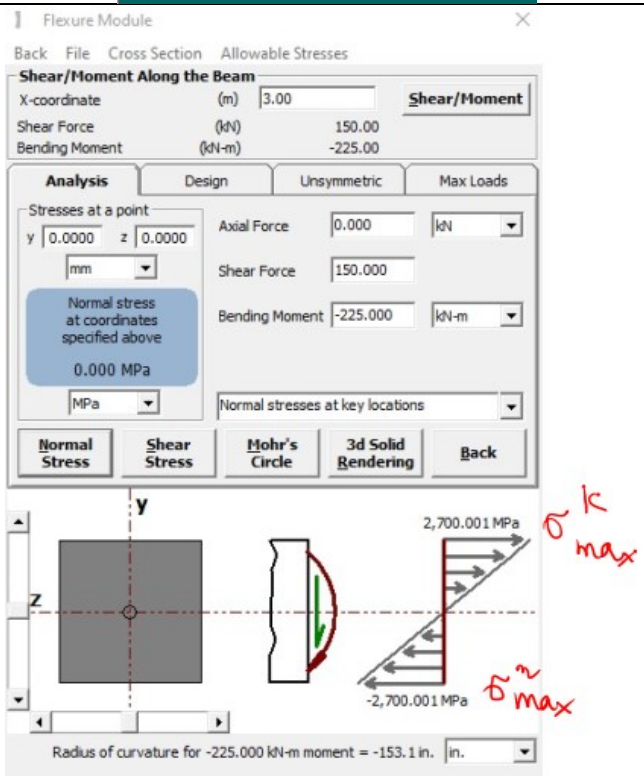
study. This is an integrated tool between theoretical teaching, manual calculations, illustrating results with Mdsolids software, helping students to be confident in self-study and self-solving exercises at home. At the same time, the software helps teachers save time to explain confusing concepts to students. Mdsolids is easy to use and fast, lightweight, and easy to install. Therefore, Mdsolids is very flexible to install on personal laptops, supporting students to study in class, in order to help students master theoretical knowledge, calculation skills, analysis, assessment and synthesis in the materials mechanics problems. The survey results showed that the student satisfaction rate is very high when integrating Mdsolids in teaching the strength of materials for engineering technology students.

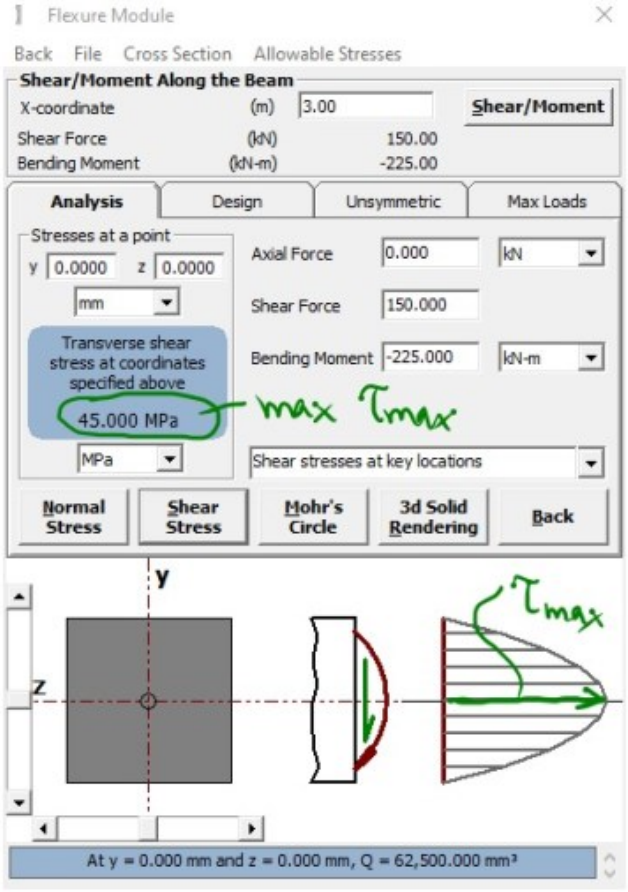
TABLE I.
TEACHING CONTENTS AND MDSOLIDS APPLICATION

Unit	Duration (hour)	Lesson Expected Learning Outcomes (LLOs)	Description of Lesson content	Mdsolids illustration
1	5 hrs	After completing this lesson, students will: - Explain the basic concepts of strength of materials. - Distinguish the types of bonds and indicate the corresponding types of bonding reactions. - Identify the system of deformation and displacement types and relate to the field of automotive engineering technology	Chapter 1. Basic concepts of strength of materials 1.1. Tasks and objects of the course 1.2. Body geometry 1.3. External forces, linkages, and reactions 1.4. Basic assumptions. 1.5. Types of deformation and displacement	
2	5 hrs	After completing this lesson, students will: - Analyze internal forces, state the cross-sectional method. - Identify internal force components - relationship between stress and internal force components. - Present and build internal force diagram. - Implement planar problem, differential relationship between internal force and distributed load	Chapter 2. Internal force theory 2.1. Concept of internal force, section method - stress 2.1.1. power 2.1.2. Cross-sectional methods 2.1.3. Stress 2.2. Internal force components, how to determine 2.2.1. Internal force components 2.2.2 How to determine internal force 2.3. Relationship between stress and internal force components	

Unit	Duration (hour)	Lesson Expected Learning Outcomes (LLOs)	Description of Lesson content	Mdsolids illustration
			2.4. Plane problem – Internal force diagram 2.6. Differential relationship between internal force and distributed load.	
3	5 hrs	After completing this lesson, students will: - Analyze what is tensile and compressive related in reality - Apply stress and deformation problems from the properties of materials - Identify and present the stability conditions, thereby solving three basic problems as well as the statically indeterminate problem - Make connections/mapping from reality to solve problems used in the field of automotive engineering technology	Chapter 3. Bar under tension and compression 3.1. Concepts 3.2. Stress 3.3. Strain 3.4. Mechanical properties of materials 3.5. Stable conditions, three basic problems 2.6. Statically indeterminate problem	

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Unit	Duration (hour)	Lesson Expected Learning Outcomes (LLOs)	Description of Lesson content	Mdsolids illustration
4	5 hrs	After completing this lesson, students will: - Identify and present concepts of torsion, deformation in cross section, torsion strain and angular strain. - Solve problems of torsion, calculate strength conditions, hard conditions, statically indeterminate problem, related to the field of automotive engineering technology.	Chapter 4. Bar in Pure torsion 4.1. Concept 3.1.1. Define 3.1.2. Internal force diagram 3.1.3. Formula relating power, torque 4.2. Stress in cross-section. 4.2.1. Observe the deformation of the bar. 4.2.2. Assumptions. 4. 2.3. Stress calculation formulas 4.3. Angle distortion 4.3.1. Absolute angular distortion. 4.3.2. Relative angle distortion. 4.4. Calculation of torsion. 4.4.1. Durable condition. 4.4.2. Hard conditions. 4.5. Statically indeterminate problem 4.6. Twist bar of rectangular cross-section	 
5	5 hrs	After completing this lesson, students will: - Analyze what is pure bending, the stresses generated on the cross-section, state and calculate the strength condition, bending moment of some sections. - Recognize flat horizontal bending, calculate stress, check durability of machine elements. - Calculating three basic problems of plane bending, uniform bending beam and elastic deformation potential energy	Chapter 5. Planar bending straight bar 5.1. Concept 5.2. Pure bending 4.2.1. Define 4.2.2. Stress in cross section 4.2.3. Anti-bending moment of some sections 4.2.4. Durable condition 5.3. Complex bending 4.3.1. Define 4.3.2. Stress on cross section 4.3.3. Durability test 4.3.4. Three basic math problems 4.3.5. Beams resist even bending 4.3.6. Elastic deformation potential energy	

Unit	Duration (hour)	Lesson Expected Learning Outcomes (LLOs)	Description of Lesson content	Mdsolids illustration
6	5 hrs	After completing this lesson, students will: - Describe the nature of complex bearing bars: pure bending, tensile or compressive bending, or torsion. - Analyze the stress generated when the bar is subjected to complex loads on the cross-sections, build stress charts - Be able to relate to reality to solve motion problems used in the field of automotive engineering technology	Chapter 6. Bars under complicated loadings 6.1. Concept 6.2. pure bending 6.2.1. Define 6.2.2. Stress 6.2.3. Neutral line and stress plot 6.2.4. Extreme stress and endurance conditions 6.3. Bending + pulling (compression) 6.3.1. Define 6.3.2. Stress 6.3.3. Neutral line, stress plot 6.3.4. Extreme stress, strength condition 6.3.5. Core of section 6.4. Bending and torsion 6.4.1. Define 6.4.2. Rectangular section bar 6.4.3. Round section bar	

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