CHAPTER 1
PROJECT BACKGROUND

1.1 Background of Study

Statics is a core subject in UTP for Mechanical and Civil Engineering programs and typically taught in lecture format. In entry-level engineering courses, students may face difficulty in determining which external and reaction forces must be included in free body diagrams and equations of equilibrium. Furthermore, the stresses caused in objects by axial, torsional, bending, and combined loadings are difficult for students to visualize.

Lawrence O. Hamer, professor in Marketing at DePaul University wrote an article in April 2000 (Hamer, 2000) where he did a research by comparing test grades from students taking lecture-only course with those students taking lecture-only course combined with various types of active learning techniques. These active learning techniques include hand-on model, pausing every ten minutes for students to flash back, discuss lecturer material and short-term, long-term group projects. Later, both groups of students took a multiple-choice exam with both definition answers and concept application answers. The result of the exam showed that students taking the lecture-only course combined with various types of active learning techniques—performed "significantly better" than students taking lecture-only course (74% correct vs. 69% correct). Hamer suggested that the difference of the result was due to the active learning format (lecture-only course combined with various types of active learning techniques) allowed poor-performance students to elaborate more on concepts that they did not understand.

David Kolb, an American education theorist defined learning as “the process whereby knowledge is created through the transformation of experience” (Kolb, 1984). According to Kolb, students must interact physically with the material being studied in order to understand it completely. By interact physically with the material being studied, it helps students to learn in a continuous cycle in which they are able to form abstract concepts and generalizations, tests the implications of these concepts in new situations via concrete experience through real-life experiences and then reflects on what was being observed. Next time when student face the same situation he/she already have the knowledge gained from the first cycle and will be able to move on to more complicated experiences with the same or similar material. It is crucial to execute different learning method along with the usual lecture because students learn in various ways. For example, incorporating the use of touch and visualization into the learning process with pull, bend and twist a structure, viewing the resulted reactions, deformations and stresses will helps in the development of student skills in solving and analyzing problems.

Hence, a learning kit for Statics is introduced since it enables students to have better understanding in the fundamental of Statics. It can provide eleven settings/experiments and demonstrations. The settings cover the chapters of force vector, equilibrium of a particle, force system resultants, equilibrium of a rigid body, force table and torque in different direction.

1.2 Problem Statement

1.2.1 Problem Identification

It is noticeable that most students face difficulty in understanding engineering concepts while studying Statics because the lack of visualization of abstract ideas, such as forces and moments. This is especially true for students with learning styles of visualizing and sensing. As a result, these will have troubles to draw free body-diagrams for 3D or finding internal forces in a frame or machine, skills necessary for learning deforms as they do not has the strong basics. Furthermore, they are unable to grasp the important concepts and face further difficulty in advanced courses such as Solid Mechanics and Dynamics, where good understanding of Statics is required. There are many studies and literature showing that students learn better when they can interact physically with the material during learning process. Research showed that there is a relationship between number of senses engaged during learning process and the amount and quality of retention achieved over time (Stice, 1987). Lecturers must learn "how to increase the productivity of their teaching" (Cross, 1991) to allow students be able to learn and retain more. If lecturers are able to increase the productivity, students not only will have a higher level of retention of structural concepts, but also will be able to move on to complex structural and build concepts more quickly.

1.2.2 Significance of the Project

This project is significant as it will help to improve the quality of education for students in Statics by allowing them to test theoretical concepts in a hands-on learning kit or teaching equipments that suit their Statics lecture class. For instance, the model of a learning object will help students in visualizing abstract ideas, problem formulation and enhanced the learning. As a consequence, student from the university will be more confident and more prepare to enter the working industries as they had gained the exposure towards more structural concepts.

1.3 Objective

The objective of this project is to design and fabricate a model of learning kit for Statics subject in order to enhance students' learning process and engage them with active experimentation at their own pace.

1.3.1 Scope of the Study

The scope is to analyze student's problems in learning Statics, and design a model of learning kit which is feasible, affordable, and interesting to students will be able to interests the students. The existing learning equipment in the market will be analyzed in order to get the idea and inspiration on design of the learning kit for Statics subject. The investigation is done via attending Statics class in order to understand and to evaluate the problems faced by students while learning Statics during the class. The design of a model of learning kit shall be developed based on data gathering from the analyzing and evaluation on the learning kit should be done to ensure it effectiveness.

1.4 Feasibility of the project

1.4.1 Schedule and availability of the tools

This project needs approximately 40 weeks to design and develop the learning kit for Statics subjects. The schedule is planned as 16 weeks for doing research, the subsequent 16 weeks for fabrication of the learning kit and another 8 weeks will be used for data collection and also analyzing feedback of the learning model. By the end of the first semester, the fabrication of the model of learning kit is expected to be done. And in the second semester, the model of learning is tested and evaluated in Statics class and improvement of the design will be adjusted based on the survey. Thus, the project can be completed in the given time period with well and proper scheduling.

The equipment and tools require to fabricate the model of the learning kit are identified. Unigraphic, AutoCad and drilling machine are the software, equipments and tools which need to be used in this project to in order to fabricate the learning model. The equipments can get easily as they are available in the UTP, this will definitely help to cut down the time-consumption and increase the feasibility of the project.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to Statics

Statics is an introductory engineering mechanics course and it is among the first engineering courses encountered by most students. Statics is the branch of physics concerned with the analysis of loads (force, torque/moment) on physical systems in static equilibrium, that is, in a state where the relative positions of subsystems do not vary over time, or where components and structures are at rest.

To maintain equilibrium, it is necessary to satisfy Newton's first law of motion, which requires the resultant force acting on a particle to be equal to zero. (R.C. Hibbeler, 2004). By Newton's second law, this situation implies that the net force and net torque on every body in the system is zero, meaning that for every force bearing upon a member, there must be an equal and opposite force. From this constraint, such quantities as stress or pressure can be derived.

Statics is thoroughly used in the analysis of structures, for instance in architectural and structural engineering. Engineers are guided by the principles of Statics whenever they are involved with the design and construction of a building. Statics is one of the sciences underlying the art of structural design. Engineers need to calculate the forces and couples acting on the structure as a whole as well as on interconnected parts. Hence, engineers must have strong understanding and perception on structures in equilibrium and internal forces in order to design the bridge. Besides, Statics also apply in music instrument such as piano. The loads that the legs of the piano must be designed to support depend not only on the piano's weight but also on the position of its center of mass which is the point at which the weight effectively acts. Also, the force necessary to hold the extensible platform in equilibrium can be determined by subjecting the platform to a hypothetical motion and applying the concept of virtual work and potential energy.

Students must have strong fundamental of knowledge in Statics in order to design things. Student without the basics of Statics will make a mistake by design a door using single hinge to support it without considering the resulting moments.

Student will be frustrated and unable to cope with the subject if he/she failed in Statics. This is because student cannot register for Dynamic subject in the coming semester. If a student cannot comprehend on an object in static, how he/she comprehend an object which is accelerated in dynamics. Hence, a learning kit of Statics is design to assist students in visualizing abstract ideas, problem formulation and enhance learning opportunities.

2.2 Student's learning style and learning processes

2.2.1 Student's learning style: Kolb learning styles

There are 4 Kolb's learning styles as shown below (www.businessballs.com):

- Diverging (feeling and watching) - These people are able to look at things from different perspectives. They are sensitive. They prefer to watch rather than do, tending to gather information and use imagination to solve problems. Kolb called this style 'Diverging' because these people perform better in situations that require ideas-generation, for example, brainstorming.

- Assimilating (watching and thinking) - The assimilating learning preference is for a concise, logical approach. These people require good clear explanation rather than practical opportunity. People with an Assimilating learning style are less focused on people and more interested in ideas and abstract concepts. People with this style are more attracted to logically sound theories than approaches based on practical value. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.

- Converging (doing and thinking) - People with a converging learning style can solve problems and will use their learning to find solutions to practical issues. They can solve problems and make decisions by finding solutions to questions and problems. People with a Converging learning style are more attracted to technical tasks and problems than social or interpersonal issues. People with a Converging style like to experiment with new ideas, to simulate, and to work with practical applications.

- Accommodating (doing and feeling) - The accommodating learning style is 'hands-on', and relies on intuition rather than logic. These people use other people's analysis, and prefer to take a practical, experiential approach. They are attracted to new challenges and experiences, and to carrying out plans. They commonly act on 'gut' instinct rather than logical analysis. People with an accommodating learning style will tend to rely on others for information than carry out their own analysis. This learning style is prevalent and useful in roles requiring action and initiative. People with an accommodating learning style prefer to work in teams to complete tasks. They set targets and actively work in the field trying different ways to achieve an objective.

2.2.2 Student's learning process: Kolb Cycle

The Kolb model describes an entire cycle around which a learning experience progresses (Kolb 1984). The goal, therefore, is to structure learning activities that will proceed completely around this cycle, providing the maximum opportunity for full comprehension. This model has been used extensively to evaluate and enhance teaching in engineering [Murphy, 1998]. Kolb argue that the learning cycle can begin at any one of the four points and that it should really be approached as a continuous spiral. According to Kolb, the learning cycle involves four processes (Figure 1) that must be present for learning to occur (www.practicebasedlearning.org):

- Concrete Experience

Concrete experience concerned with something that has happened to students or what students done. Also, it concerned with ability of students adopt new ideas into practice.

- Reflective and Observation

Reflection and observation concerned with reviewing the event or experience in students mind and exploring what students did and how students did to feel about it.

- Abstract Conceptualization

Abstract conceptualization concerned with developing an understanding of what happened by seeking more information and forming new ideas about ways of doing things in the future.

- Active Experimentation

Active experimentation concerned with trying out the new ideas as a result of the learning from earlier experience and reflection.

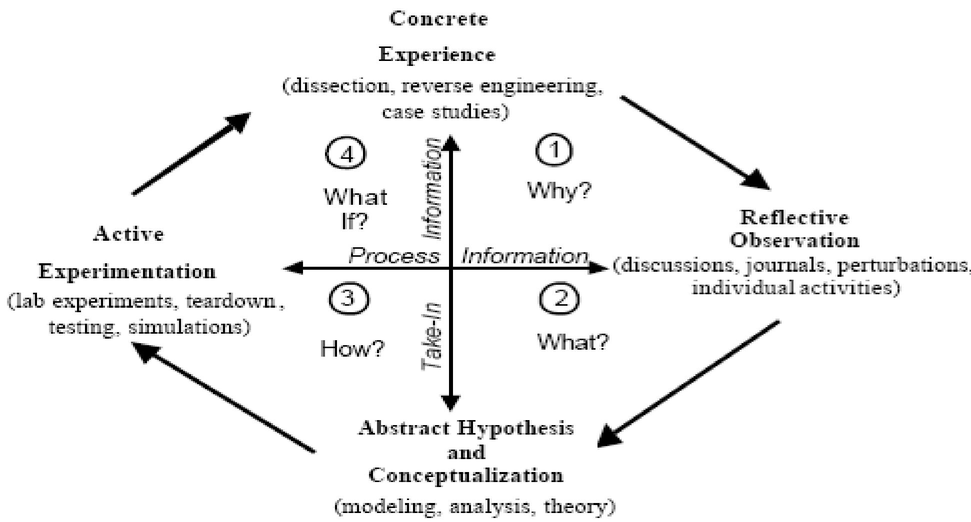


Figure 1: Overview of Kolb cycle (www.practicebasedlearning.org)

Analysis on literature of Student's learning style and learning processes

Before starting to design a learning kit, the understanding on student learning style and student learning process are needed in order to ensure that the existence of learning kit is necessary and helpful to assist student to understand the concept of Statics.

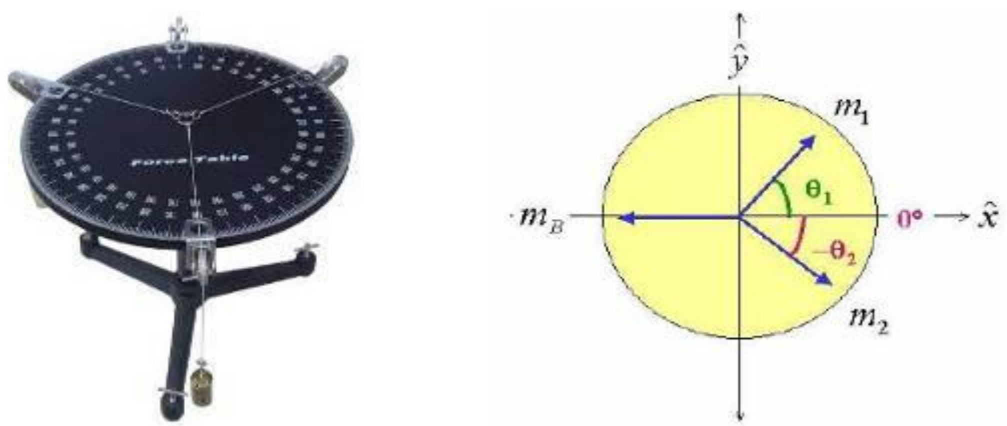
According to Kolb's learning style, the learning styles of students are classified as diverging, assimilating, converging and accommodating. For converging learning style, they prefer technical tasks, and are less concerned with people and interpersonal aspects. People with a converging learning style are best at finding practical uses for ideas and theories. Also, for the accommodating learning style is 'hands-on', and relies on intuition rather than logic. Hence, a learning kit is suitable in assisting student for better understanding on Statics who is either converging style learner or accommodating style learner. After hand-on learning kit, both accommodating style learner and converging style learner will have better comprehension.

David Kolb defines learning as “the process whereby knowledge is created through the transformation of experience”. (Kolb, 1984). According to Kolb, students must physically interact with the material being studied in order to understand it completely. Hence, learning kit is useful in assist student for better understanding.

2.3 Existing learning tools and equipments

2.3.1 Force Table

The force table consists of a horizontal circular table with a removable peg at its center. An angular scale is provided around its edge, where pulleys may be clamped. A string passes over each pulley, one end of which is connected to a ring at the center of the table and the other to a weight hanger. (www.people.hws.edu)



(a) (b)

Figure 2: Force table (www.people.hws.edu)

PROCEDURE

The ring is acted on by three forces, whose magnitudes depend on how much weight is placed on each weight hanger, and whose directions depend on the directions assumed by the strings. If the three forces do not add up to zero, the ring will tend to move in the direction of the net force, and it will move until it reaches a new position where the new forces (new because the directions have changed) do add up to zero. The equilibrium position, and say that the ring is in equilibrium because it has no tendency to move away from this point.

1. Student will be assigned a set of three angles. Set the pulleys at those angles.
2. With the pin in place in the center of the table, place some weights on the weight hangers. When choosing weights in this experiment avoid choosing very light ones, but do not exceed about 500 grams. Adjust the amount of weight on each hanger until you succeed in stabilizing the ring exactly at the center of the table (the pin will be at the center of the ring). Jiggle the strings after each weight change to aid the system in coming to equilibrium.
3. After achieving ring equilibrium at the center of the table, make small changes in each of the weights and observe how large a change is necessary in order to produce a noticeable change in the equilibrium position of the ring. These just noticeable weight changes are the uncertainty values that you will assign to each weight value.
4. Record the final best weights, weight uncertainties, and angles. (Include the weight of the hanger in your weight value.) This information provides you with the magnitude and direction of each force.

Question:

- Sketch the vector addition using the parallelogram.
- Under what conditions (angles) will forces is equal in magnitude on the force table?
- Calculate the force magnitude, milligram, applied to each string

Analysis on Force table

After hands-on force table, students will be able to verify the laws of triangle, parallelogram and polygon of forces. The force table can be used to test the vector nature of force, show that in static equilibrium the vector sum of forces is zero and practice resolving vectors into components. Through hand-on force table, students would have strong fundamental of Statics in equilibrium and parallelogram.

2.3.2 Shear, Moment and Bending Lab

The shear, moment and bending lab is conducted at Virginia lab Tech (USA) (refer to Appendix A). The Shear, Moment, and Bending Lab is designed to teach students to identify shear force and calculate maximum shear, identify and calculate maximum moment, identify tension and compression in loaded beams, and to represent shear and moment graphically. For this lab PVC pipes are used as beams. One beam is pinned at one end and on a roller at the other with weights hung from it to impart a moment. Students are first asked to compute the moment for the beam and draw the shear and moment diagram (See Appendix A: Figure 3a, Step 1). Next a second PVC "beam", exactly half the length of the first beam and pinned at one end, is placed in front of the first PVC beam (see Appendix A: Figure 3a, Step 2). This second beam has a "T-bar" at its center. Students are asked to attach scales to the arms of the T-bar and apply force until the shape of the second beam matches that of the first beam (the beam loaded with weights). After reading the scales they are asked to calculate the moment in the beam to learn that it is the same as the moment being applied by the weights. (Christopher G. Alcorn, 2003).

As a summary, students are allowed to test their hypothesis on the demonstration by measuring forces and manipulating the demonstration on moment to see how different scenarios behave. Throughout this lab, student will be able to discuss the concept of shear force, moment, tension and compression in loaded beams. Thus, this lab aid students in develop a strong understanding and perception on shear, moment and bending.

Analysis on shear, moment and bending lab

The literatures review for the labs demonstrate that Statics can be teach in hands-on learning kit/equipments for students in order to enhance their understanding on Statics and problem solving. For examples, students are able to calculate maximum shear and maximum moment represent shear and moment graphically and identify tension and compression in loaded beams. Students would benefit from being able to touch and sense Statics concepts via the teaching equipments at the lab during the equilibrium lab and shear, moment and bending lab.

Students who involved in these labs will come out with a better performance during their final exam. Hence, the lab is effective and yet assisting students to have better understanding in shear, moment and bending lab. With continuing support and refinement, the hands-on- learning kit/equipments for Statics has all of the necessary attributes and efficiency to help students, to reach a higher level of proficiency in Statics so that future Architecture, Engineering, and Building Construction classes can move forward at a faster pace.

2.3.3 Hands-on Learning Tools for Engineering Mechanics

Engineering Faculty at Rowan University are developing hands-on and visualization tools for use in mechanics courses. The tools for Statics involve hands-on demonstrations and visualization in real time for determination and measurement of reaction forces and moments due to forces imposed onto a bar or structure by a student. Often students can solve equations of equilibrium but have difficulty in understanding force and moment components. Also, students have difficulties understanding the reactions generated by specific constraints on a bar (e.g. pinned, rigid, or free). These difficulties interfere with the formulation of equations needed to solve a problem and the understanding of material that is presented later. To allow students to experience reaction forces and moments, two simple experiments will be developed. The first experiment involves two beams, one with a fixed end constraint, the other with a ball and socket end constraint (Figure 4). These beams will allow the students to push on the free ends of the beams and witness the effects at the constrained end.

The second experiment is simply a rod with handles (Figure 5.) One student holds the handles, while another student applies a force at the opposite end of the rod. The student holding the handles feels the reaction force and moment necessary to prevent the rod from moving. Both of these experiments are designed to improve students' ability to sense reaction forces and moments intuitively. (Jennifer Kadlowec, 2002)

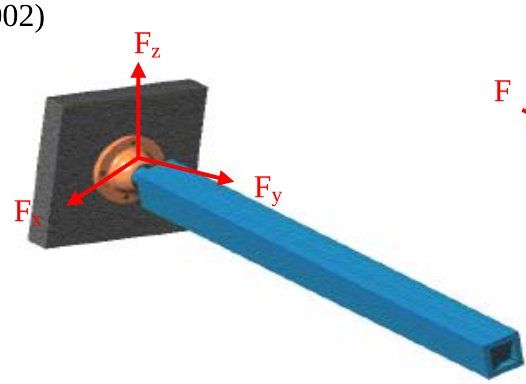


Figure 4: Beam with ball and socket constraint

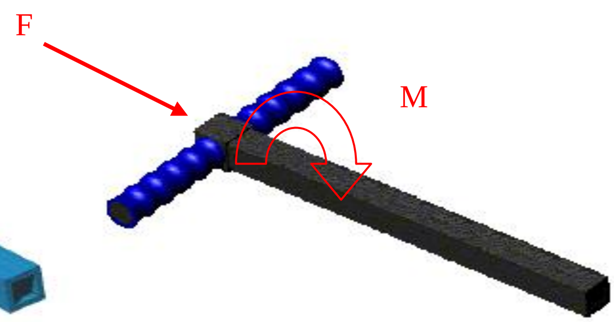


Figure 5: Beam with reaction handles

Analysis on Hands-on Learning Tools for Engineering Mechanics

The tools are designed to help students address difficulties in working with reaction force and moment. The tools are being developed so that critical thinking and problem solving skills of students will be improved by engaging them in the learning process through individual experimentation. The equipment will have a positive an impact on student learning in courses the mechanical and civil Engineering programs as well as benefit students with various learning styles which are converging and accommodating learners.

2.3.4 Bending moment and shearing force learning equipment

The bending moment and shearing force learning equipment is available at UTP in Solid Mechanics Lab (block 18). The objective of this experiment are to show that any section of a beam subjected to transverse loads, the shearing force is defined as the algebraic sum of the transverse components of forces located at one side of the section. In addition, the bending moment is defined as the algebraic sum of the moments of the force to one side of the section.

Apparatus:

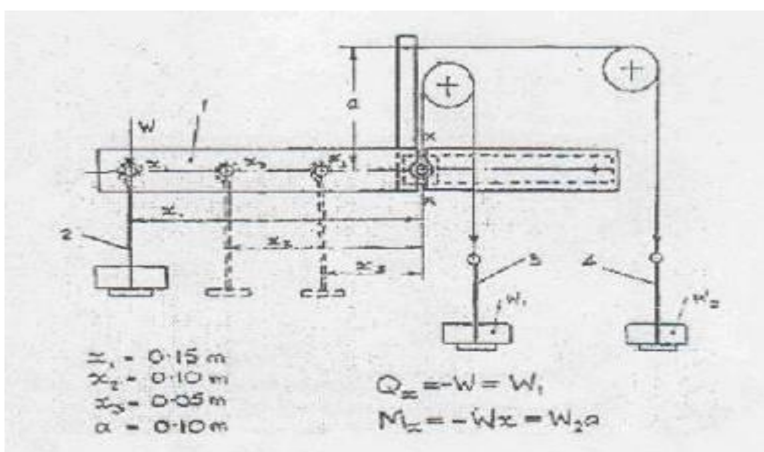


Figure 6: Schematic of bending moment and shear force apparatus

Procedure

1. Without a load applied to the beam (1), check the beam is in equilibrium.
2. Adjust the support tension springs if necessary.
3. Attach the load hanger (2) and weight to the beam at position x1 and add weight to hangers (3) and (4) until the beam returns to equilibrium position.

4. Repeat the experiment with weight in position x2 and x3.
5. Record the values for each position of the load W and draw the shearning force and bending moment diagrams.
6. Perform the experiment again with 2 additional weight values.

Analysis on Bending moment and shearing force learning equipment

Throughout the experiment, students will be able to understand clearly on internal forces (Appendix B) such as shearing force and bending moment including moment sign convention, find the values of shearing force and bending moment and draw the shear and moment diagram. The Shear and bending moment diagrams is vital for students to understand because the diagrams are useful analytical tools used in conjunction with structural analysis to help perform structural design by determining the value of shear force and bending moment at a given point of an element. Using these diagrams the type and size of a member of a given material can be easily determined. Another application of shear and moment diagrams is that the deflection can be easily determined using either the moment area method or the conjugate beam method.

2.3.5 Statics Fundamental Learning Equipment

Statics fundamental learning equipments (TecQuipment products) are design and manufactured by TQ education and Training Ltd. The kits consist of one work panel and several parts such as roller chain, spring balances and weights. The kits give 3 types of Statics experiment in popular structure, from suspension cables to beam and ladders. The first type is the equilibrium of rigid body (EORB) experiment (Figure7) demonstrates the force on a ladder type structure at different angle, with a known mass at different positions. Follow by the equilibrium of force (EOF) experiment (Figure 8) shows the concurrent and concurrent coplanar forces and condition for equilibrium. The third type is the equilibrium of beam (EOB) experiment (figure 9) which demonstrates the forces, moment and reaction of a rigid beam. (www.TQ.com)

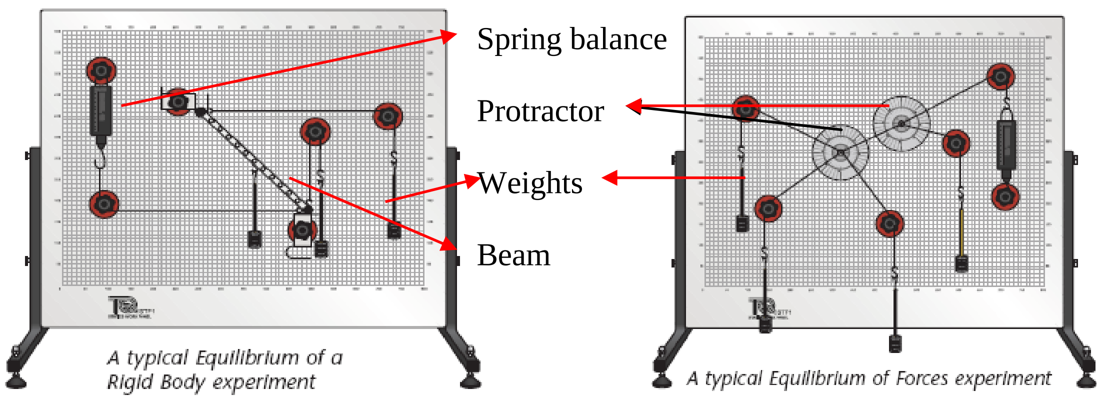


Figure 7: learning kit of EORB experiment

Figure 8: learning kit of EOF experiment

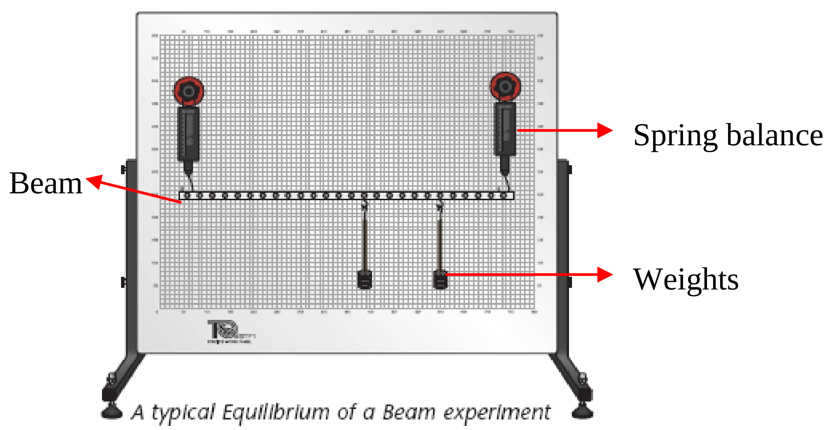


Figure 9: learning kit of EOB experiment

Analysis on Statics Fundamental Learning Equipment

The Statics fundamental learning equipment/kit can provide visualization for classroom demonstration and can be use by small group of students. Besides that, the main advantages of this kit can cover wide range of chapter in Statics if compare with previous existing learning equipment such as force table. Also, this kit allows students to build and change experiment for improved understanding.

CHAPTER 3
METHODOLOGY

3.1 Flow Chart

The planned-work flow for the project is as shown in Figure 10.

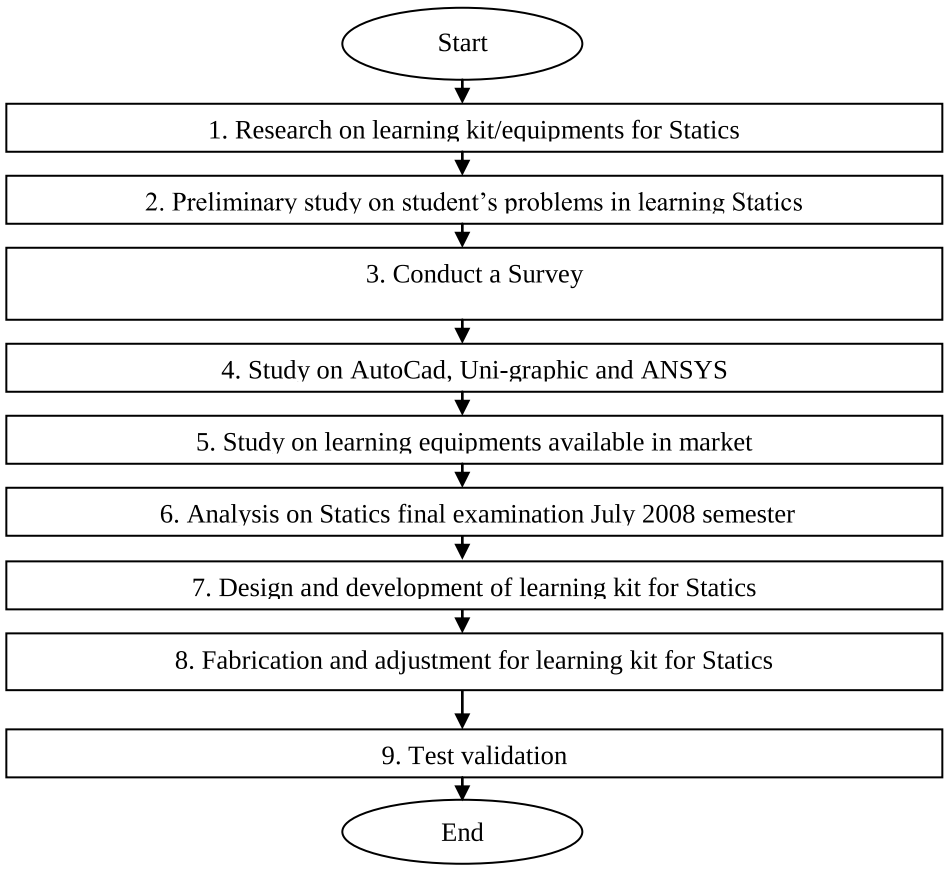


Figure 10: The flow chart of planned work

The explanation of the flow chat (Figure 10) is shown below:

1. Research on learning kit/equipments for Statics via internet and IRC resources. The research contains theories, hypotheses and data which are relevant to design

and development of hands-on learning kit for Statics. There are several researches on hands-on learning equipments and lab such as equilibrium lab had been done in order to enhance students understanding on Statics.

2. Preliminary study on student's problems in learning Statics. It will be done through by attending the Statics class and observing whether students have difficulty in learning Statics.
3. Conduct a survey on students in order to classify them by grade of physics, study on student's problems in learning Statics, figure out student's preferable learning style such as learning via lecture mode or lab mode and find our which chapter is most difficult for students to comprehend in learning Statics.
4. Study on CAD software such as AutoCad and Uni-graphic is necessary in designing the learning kit for Statics and ANSYS is studied for analysis the stress distribution of the learning kit stand.
5. Study on learning equipments available at block 18 (solid mechanics lab) and learning equipments available in market are helpful in designing the learning kit.
6. The analysis on Statics final examination July 2008 semester is important in determines the scope of designing learning kit. The analysis is done through: Firstly, divide students into good and poor performance. Then determine whether early chapters of force vectors, equilibrium of a particle and rigid body, force system resultants and are prerequisite for student to perform well in later chapter.
7. Design and development of learning kit include design specification, general conceptual design, evaluation of selection of designs, material selection, details design, bill of materials and engineering design analysis.
8. Fabrication and adjustment of learning kit for Statics is done via CNC and drilling machine.

9. The test validation is performed to ensure the learning kit can enhance students' learning process. The test and validation is done through: Firstly, one student is selected in batch Jan 2009 who failed in Statics Final Examination July 2008. Then, one test will be conducted to the student before participant in hands-on learning kit and another test will be conducted after hands-on the learning kit. The tests result will be compared.

3.2 PROJECT ACTIVITIES

Project activities involve:

- Conducting a survey
- Attending for Statics classes
- Study on uni-graphic
- Study on learning equipments in block 18

Conduct a survey

Conduct a survey on students in order to classify them by grade of physics, study on student's problems in learning Statics, figure out student's preferable learning style such as learning via lecture mode or lab mode and find our which chapter is most difficult for students to comprehend in learning Statics.

Attend Statics classes

Preliminary study on student's problems in learning Statics by attending Statics classes and the purpose is to observe whether students have difficulty in learning Statics. Students may have difficulty when come to questions that involve Cartesian vector and supports (such as single hinge and single journal bearing with square shaft) for rigid bodies subjected to 3-dimensional force system

Study on uni-graphic

Learning on how to getting start on NX (such as mouse navigation, pau_intro_1.prt, application: modeling & manufacturing), create, edit the shapes such as cylinder, cone, box, make holes, chamfer and fillet. This study is important because learning kit is design by using uni-graphic and transforms from drawing to NC program.

Study on learning equipments in block 18

Throughout the experiment, students will be able to understand clearly on:

- Shearing force and bending moment including moment sign convention
- Find the values of shearing force and bending moment
- Draw the shear and moment diagram to help perform structural design by determining the value of shear force and bending moment at a given point of an element for future use in career.

3.3 HARDWARE/TOOLS AND SOFTWARE REQUIRED

Designing a learning kit is the combined of software and hardware, e.g. using the software to draw the draft and blueprint, conduct some simulation and analysis to understand and predict its possible behavior, fabricating the product by using certain machine in order to get the accurate dimension and tolerance, surface finishing by using machining tools, etc. Thus, there are few software and hardware that are needed in this project. Tables below show the list of software and hardware.

Table 1: List of software needed

Software	Function / Use
AutoCAD 2004/ Uni-graphic	Draw technical drawings and blueprint for CNC machining
CATIA V5	Draw part body and assembly drawings
Microsoft Word	Write reports

Microsoft Excel	Organize data for easier comprehension and create spreadsheet to perform certain calculation

Table 2: List of hardware needed

Hardware	Functions / Use
Rapid- prototyping / Injection molding	Fabricate part body (plastic)
EDM / CNC	Machining part body with high precision

The Gantt charts are shown in Appendix C.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Results from Questionnaires (see Appendix D for questionnaires):

There are total numbers of 302 respondents from different year responded to the survey. 124 respondents and 104 respondents are from year 1 and year 2 respectively (Figure 11). Out of the total number of 302 undergraduate respondents, there are 214 male and 88 female (Figure 12). Among the respondents are 240 Malays, 36 Chinese and 8 Indians; the other 18 remaining are from other ethnic group (Figure 13). For the entry level, 253 respondents are from Foundation, 7 respondents from Matriculation, 10 and 5 respondents from STPM and Diploma respectively (Figure 14).

Section A: Demographic

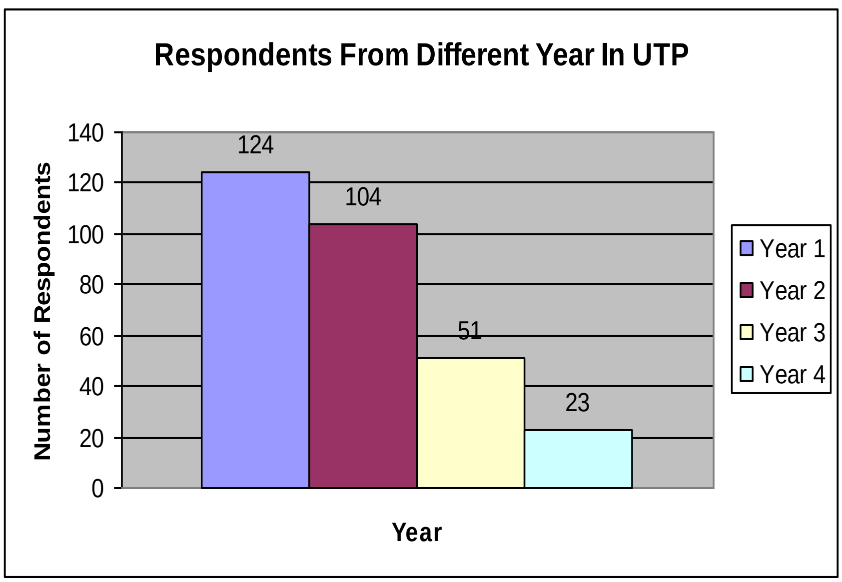


Figure 11: Histogram of respondents from different year in UTP

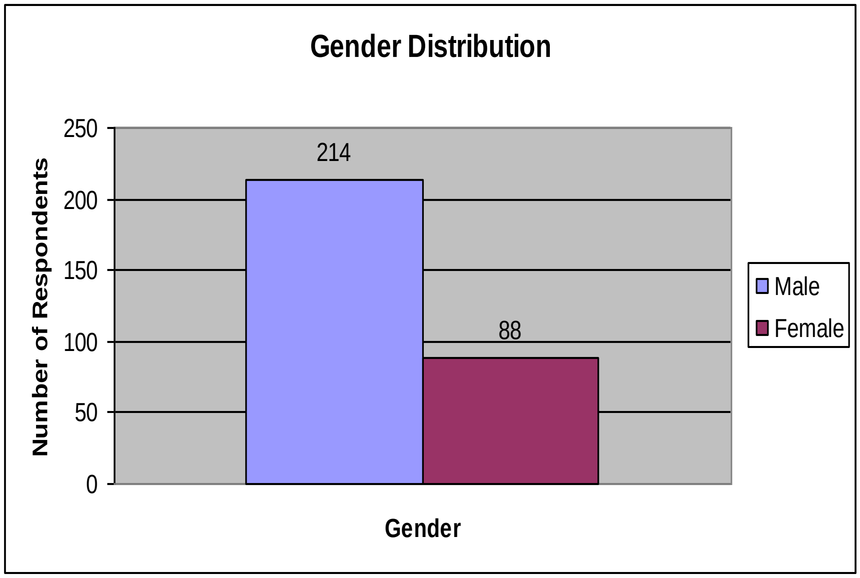


Figure 12: Histogram for gender distribution

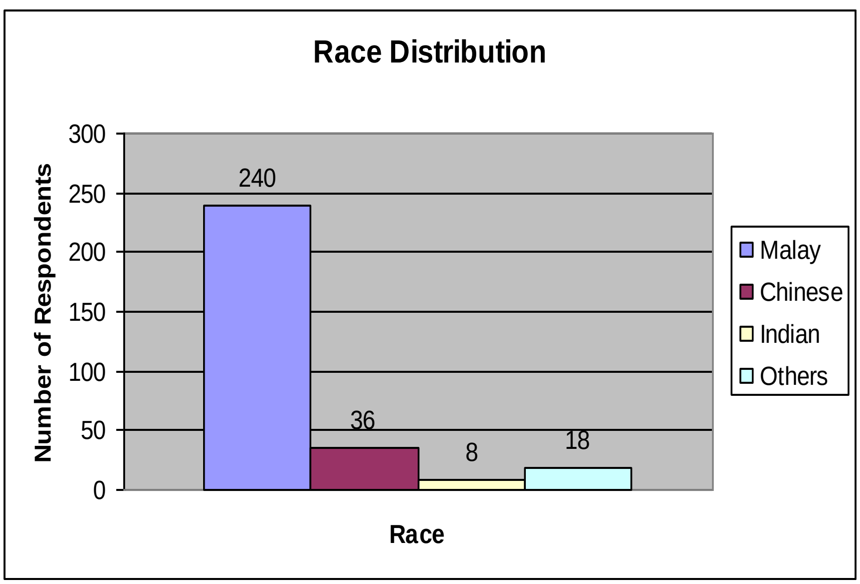


Figure 13: Histogram for Race Distribution

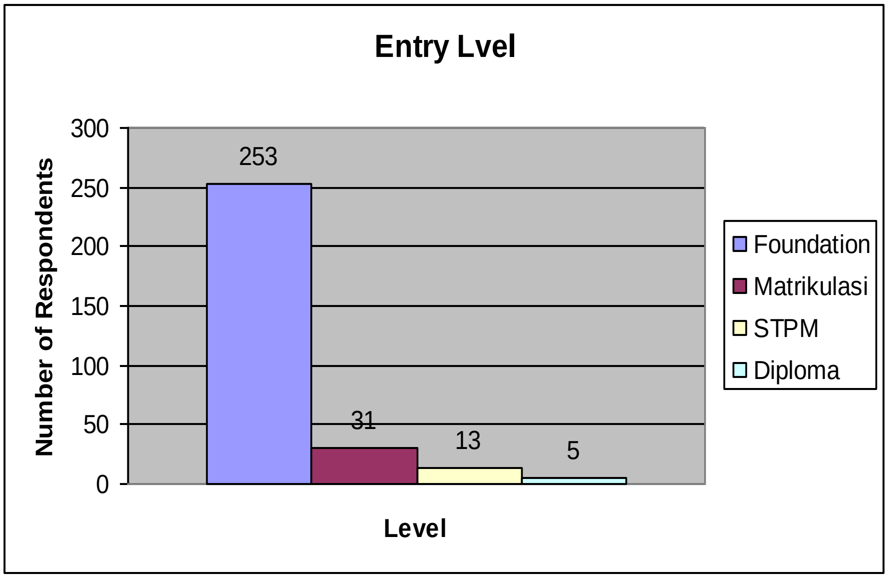


Figure 14: Histogram for entry level

Section B: Survey Information

There are 79 respondents and 62 respondents obtained grade A and A- in Foundation/Matrikulasi/STPM/Diploma level respectively. 23.18%, 16.56% and 1.66% of 302 UTP respondents obtained grade B+, B and B- in Foundation/ Matrikulasi/ STPM/Diploma level respectively. (Figure15)

53% of the 292 UTP undergraduate respondents have 1A for physics in SPM level. Following by 35% and 11% of the respondents have 2A and 3B for physics in SPM level respectively. There are 30%, 40% and 30% of the 10 UTP respondents obtain A, A- and B+ for physics in Junior High School. (Figure 16)

There are 9.27% and 2.65% of the respondents obtained grade C+ and C in Foundation/ Matrikulasi/ STPM/Diploma level respectively. This is due to the difficulty of physics level had been increased from SPM level to Foundation in UTP/Matrikulasi/STPM/Diploma level.

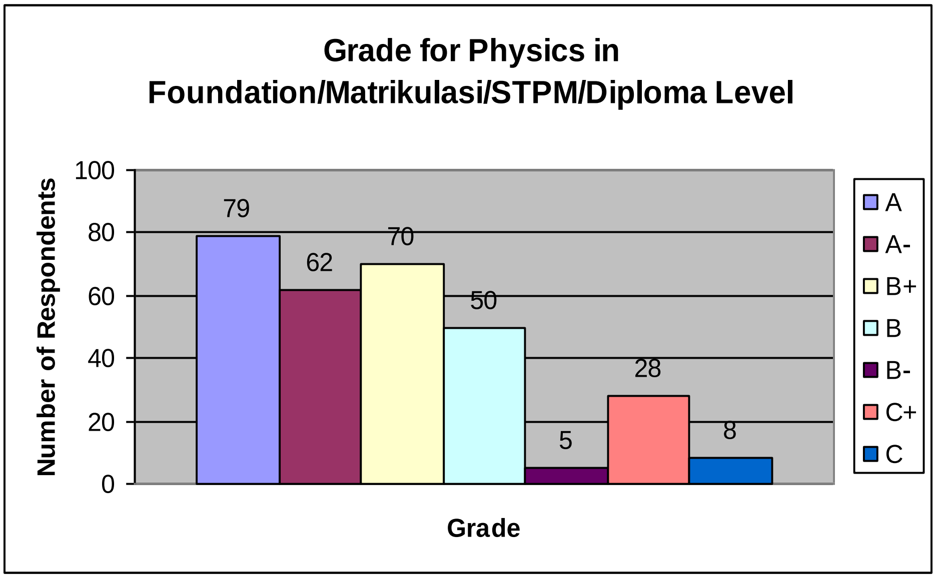
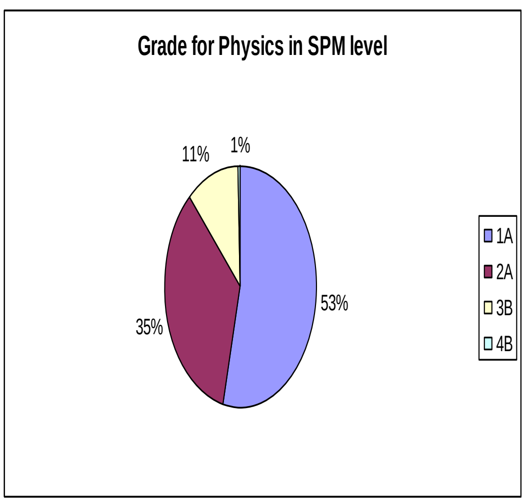


Figure 15: Histogram for grade of physics in Foundation/Matrikulasi/STPM/Diploma



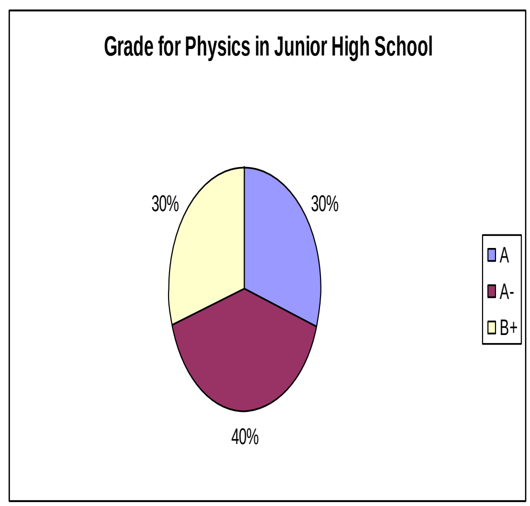


Figure 16: Pie Chart for grade of physics in SPM & Junior High School level

There are 153 respondents from Statics class can comprehend well in the chapters of Force Vectors and 143 respondents can understand well in the chapter of Equilibrium of Particle. Throughout the findings, up to 95% students able to add forces and resolve them into components using the Parallelogram Law and also comprehend well on equilibrium of a particle. This is because they have strong fundamental of physics from foundation, SPM and STPM. (Figure 17). In foundation, SPM and STPM level, students examine basic concepts such as energy, force, and friction and all that derives from these, such as mass, matter and its motion.

Some of the students begin facing difficulty in visualize and unable to calculate/express magnitude of forces and unit vectors in Cartesian vector form. Also, students face difficulty in the question that involves supports for rigid bodies subjected to 3-dimensional force system. For example, the question that involve ball-and-socket joint, single thrust bearing and single hinge. Only 119 respondents comprehend well in Force System Resultants and 93 respondents understand well in Equilibrium of a Rigid Body, the understanding on these 2 chapters has been declined 22.22% and 39.22% respectively if compare with chapter of force vector.

There are only 14 respondents from Statics class cannot comprehend well the chapter of Force Vectors and Equilibrium of Particle. The condition became even worsen when came to the chapter of Force System Resultants and Equilibrium of a Rigid Body. The number of students who cannot comprehend well on chapter of Force System Resultants and Equilibrium of a Rigid Body has been increased to 26 and 30 students respectively or in other way; it has increased almost 107% from the previous students who cannot comprehend well on the chapter of Force Vectors and Equilibrium of Particle. This is because the chapter of Force Vectors and Equilibrium of Particle involve three-dimensional questions and it is difficult for students to imagine and visualize the question for problems solving.

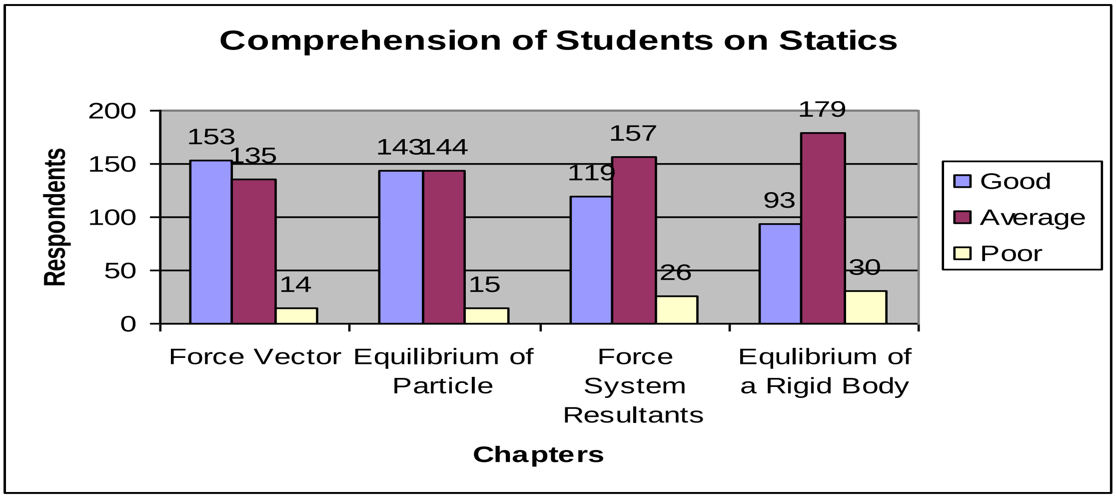


Figure 17: Histogram of comprehension of Students on Statics subject

There are 178 respondents had responded to the comprehension of Statics on chapters of structural analysis, internal forces, friction, center of gravity & centroid and moment of inertia (Figure 18). 46 and 61 respondents can comprehend well in the chapters of Structural Analysis and Internal Forces respectively. There are 22 and 19 respondent has poor understanding in the chapter of center of gravity & centroid and moment of inertia respectively.

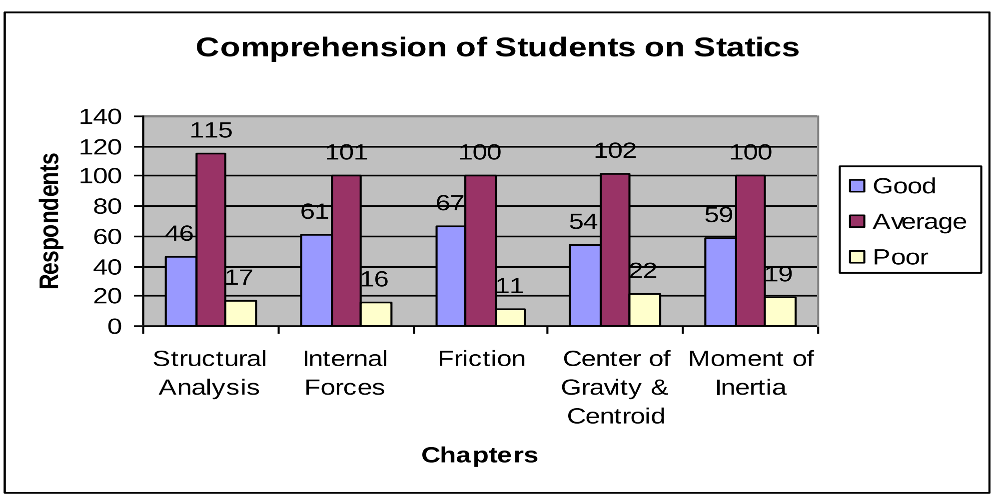


Figure 18: Histogram of comprehension of Students on Statics course

Up to 62 respondents (Figure19) from Statics class prefer lecturer mode and 52 students prefer Group Study and Discussion among friends. These results show that 37.75% of 302 respondents from Statics class or equivalent to almost 114 students adapt diverging and assimilating learning style.

There are 52 and 61 respondents from Statics class prefer lab mode and learning kit respectively. These results demonstrate that there are almost 37% of 302 students or equivalent to 113 students in the Statics class adapt converging and accommodating learning style. Hence, the existing of development a learning kit is necessary in order to assist them in understanding the subject of Statics well.

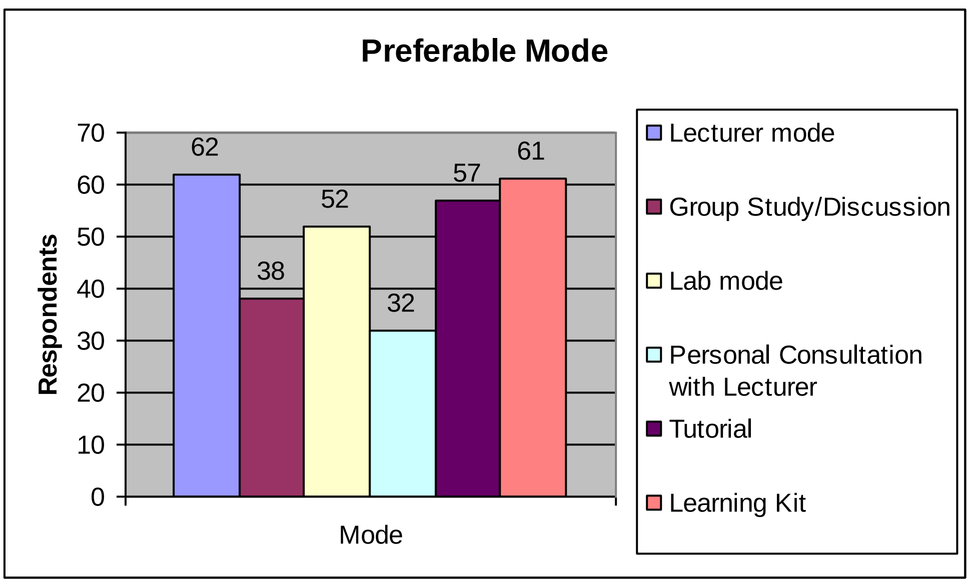


Figure 19: Histogram for Students' Preferable mode

4.1.1 Student's problems & Comments from questionnaires:

1. "Facing difficulties especially from chapter 5 onwards."
2. "Confused with the force reaction and moment direction."
3. "Not enough example from lecturer."

4. “Confused about Cartesian vectors.”
5. “Facing difficulties from chapter 6 onwards.”
6. “I am doing great in the first 5 chapters.”
7. “Facing difficulty in drawing FBD & direction of moment.”
8. “Hard to imagine.”
9. “I can’t understand the lecturer slides being taught.”
10. “It needs lots of exercise to understand the problem.”
11. “I can’t remember all the formulas.”
12. “It is hard to understand when only study the theory without application.”
13. “Hard to understand what the questions want and hard to find the information from the questions.”
14. “Careless in sign convention.”
15. “Difficult to understand and memorize the formulas.”
16. “It is hard to comprehend on force vector and moment of inertia.”
17. “Have difficulty when the component or structures become more complex.”
18. “Too much concepts need to be understand and too much equations.”
19. “Lack of exercise given from the lecturer (exercise without solutions).”

4.2 Discussion on hand-on learning kit/equipments and software program

Throughout the hands-on learning kit, students learn better when they are physically engaged in the learning process. Also, students need to physically interact with the material being studied in order to understand it completely. Physical interaction gives rise to learning in a continuous cycle in which the student forms abstract concepts and generalizations, tests the implications of these concepts in new situations via concrete experience and then reflects on what was observed. Hence, next time the student face the same situation he/she will prepared with the base of knowledge gained during the first cycle and will be able to move on to more complex experiences with the same, or similar material. The major advantage in hand-on learning equipments is “presumably” the elimination of all synchronizing activities required in a mixed lecture-lab course and greater development of measurement theory.

Discussion on software program as learning tool

There are wide ranges of scope of the subject/chapter can be covered by using software as learning tool. Several of case studies can be learnt from the software in order to guide student in problem solving. However, software program may assist student in visualization and problem solving but students can not perform physical interaction with the material shown in the software. Software program only emphasize on theoretical value but not experimental value.

4.3 Analysis on Statics Final Examination July 2008 Semester

Out of the total number of 140 undergraduate students' participant in Statics Final Examination (FE) July 2008 semester, there are 80 students performed well in answering FE Q1 to Q6 and 60 students have poor performance in answering FE Q1 to Q6 (Figure 20).

Up to 80 students have average scores of 17.4 and 17.2 (Full mark is 20) and performed well in answering FE Q1 to Q3 and Q4 to Q6 respectively. There are 60 students have average scores of 12.6 and 8.2 in answering FE Q1 to Q3 and Q4 to Q6 respectively. The average scores of good students have drop slightly from 17.4 to 17.2 which is 1.15% and the average scores of weak students have decrease from 12.6 to 8.2 which is equivalent to 35%.

The average scores showed that students who performed well in early chapter 2, 3, 4 & 5 will also perform well in later chapters that are 7, 8 & 9 since there is only differ by 1.15%. Whereas student's who have poor performance in early chapters 2, 3, 4 & 5 will also have poor performance in later chapter. Students start to face difficulties in answering later chapter's questions since they do not have strong fundamental in early chapters. Hence, early chapters of 2, 3, 4, & 5 are prerequisite and important for student to perform well in later chapter. Thus, it explains that the scope of designing learning kit only emphasized on early chapters.

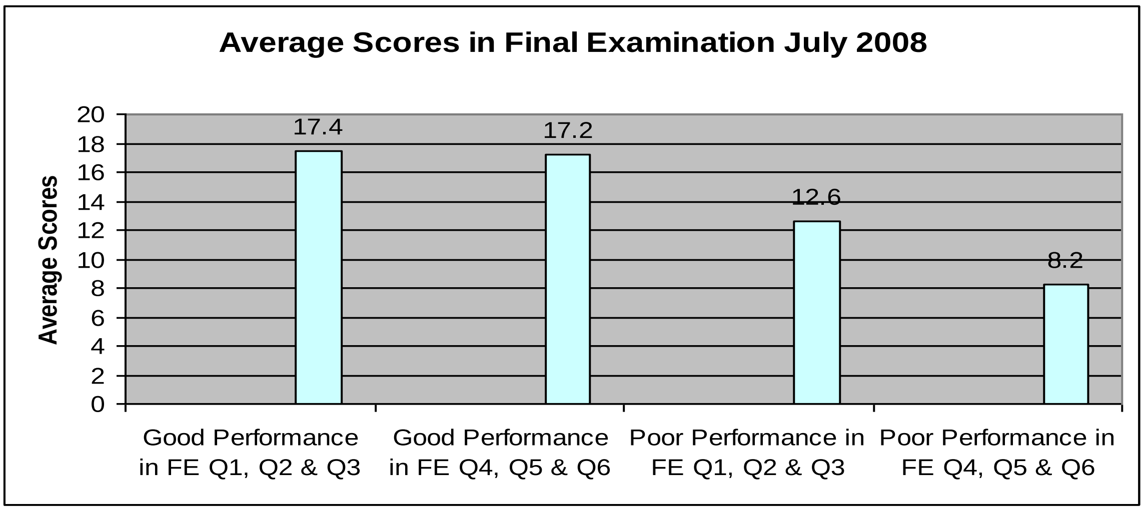


Figure 20: Histogram of Average Scores in Final Examination July 2008

Note:

Q1 covered Chapter 3 : Equilibrium of a Particle

Q2 covered Chapter 2 & 4: Force Vector and force system resultants

Q3 covered Chapter 5 : Rigid Body

Q4 covered Chapter 7 : Internal Forces

Q5 covered Chapter 8 : Friction

Q6 covered Chapter 9 : Center of Gravity

4.4 Design and development of learning kit for Statics

The design and development of learning kit is shown in Figure 21.

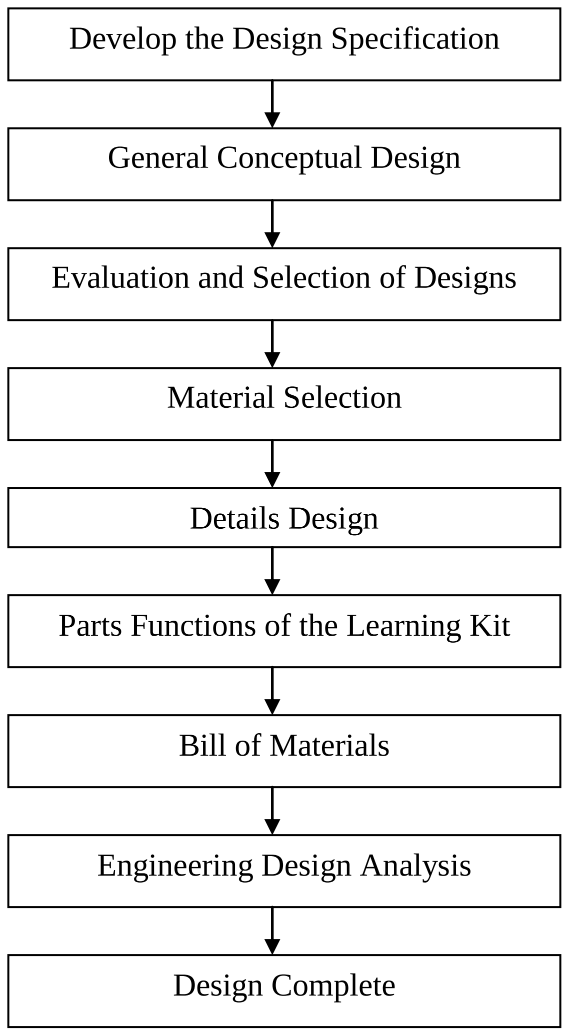


Figure 21: Design and development of learning kit

4.4.1 Design Specification

Design of the learning kit should provide various types of experiments or demonstrations to let students to be able to understand the fundamental of Statics. Also, the learning kit should involve hands-on demonstration and visualization in real time to enable students to understand reaction of force and moment components in 2-dimensional and 3-dimensional.

The demonstration of learning kit should be done in laboratory or during lecture classes. The space required for demonstration should not exceed 65cm x 65 cm and the weight of the prototype should not exceed 10kg so that it is portable and easy to carry.

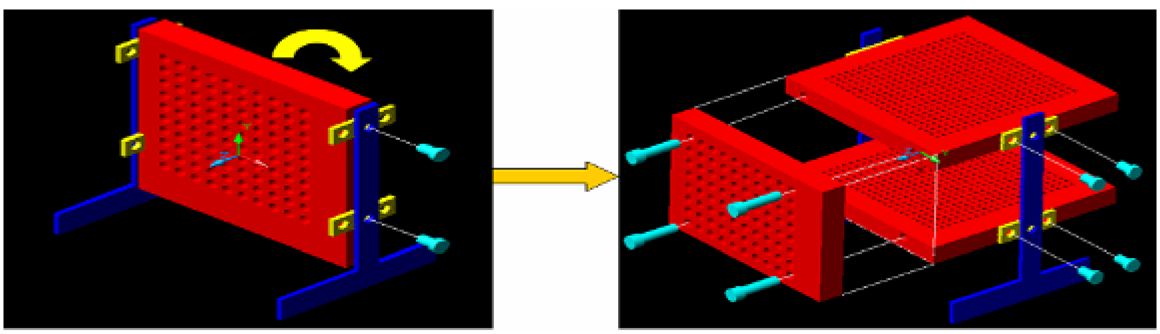
The learning kit is designed in a way that all parts of it can be dismantled and re-assembled. However, the model of the learning kit cannot be dismantled due to the welding at the joint. This is due to limited budget since all parts of the prototype are made of hollow mild steel. Hence, some of the joints of the learning kit cannot be fastened. Thus, the only limitation of the prototype is it cannot be dismantled.

4.4.2 General Conceptual Design

The conceptual designs are the rough sketches produced from the designer's earliest idea. The ideas were developed based on the outcome of the survey and the designs of learning kit were emphasized on the chapters of force vector, equilibrium of a particle, force system resultants and equilibrium of a rigid body. This is because those chapters are pre-requisite for later chapters.

The selection of the best conceptual design is done by listing out the numbers of possible criteria and evaluation for every conceptual design. The design is then rated based on each selection criteria and the total rating for each criterion is sum up to find the highest weighted score. The design with the highest weighted score will be selected.

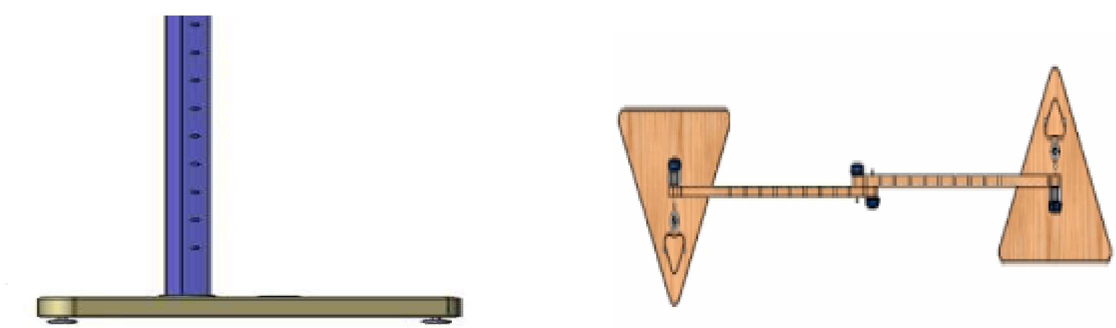
There are two conceptual designs which have the potential to solve the problem statements of the project. Both of the design can be attached with pulley, hook, protractor and springs to demonstrate various setting of problems in Statics. The learning kits allow students to change experiments to improve their understanding on Statics. In design 1 (figure 22), the learning kit can demonstrate various types of experiments in 2-dimensional (2D) and 3-dimensional (3D) and let students determinate and measure the reaction forces and moments. Meanwhile in design 2 (figure 23), the learning kit only can demonstrate Statics's experiments in 3D.



Experiment in 2D

Experiment in 3D

Figure 22: Design of learning kit 1



Side view

Top View

Figure 23: Design of learning kit 2

4.4.3 Evaluation and Selection of Designs

The list of selection criteria with evaluation of every conceptual design are stated in Table 3. It demonstrates that the design 1 has the highest weighted score compare with design 2. Hence, design 1 is adapted for this project.

Table 3: The evaluation of conceptual design

Selection Criteria	Weight	Design 1		Design 2	
	Weighting	Rating	Weighted Score	Rating	Weighted Score
Performance	10	9	90	4	40
Safety	10	8	80	9	90
Flexibility	10	7	70	8	80
Size	8	6	48	7	56
Durability	10	8	80	9	90
Cost	10	6	60	8	80
Aesthetics value	8	8	64	5	40
Total			**492**		**476**

The comment on each selection criteria of design 1 are stated in the Table 4.

Table 4: Comment on design 1

Selection Criteria	Comment
Performance	It can demonstrate various types of experiments in 2-dimensional (2D) and 3-dimensional (3D) view and let students determinate and measure the reaction forces and moments
Safety	The most danger part is at the sharp edge of the wood plane.

Flexibility	Easy to operate for all users with the guidance of operating manual.
Size	Need a space of 60cm x 60cm
Durability	Need to have maintenance on the wood plane
Cost	The stand made of mild steel increase the cost.
Aesthetics value	Bulky outlook and clear definition for every function

The comment on each selection criteria of design 2 are stated in the Table 5.

Table 5: Comment on design 2

Selection Criteria	Comment
Performance	It can only demonstrate Statics's experiments in 3D view and choice of experiments are less than design 1.
Safety	The most danger part is at the sharp edge of triangle.
Flexibility	Easy to operate for all users with the guidance of operating manual.
Size	Need a space of 50cm x 50cm (2 or 3 stands of design 2 to conduct for experiments)
Durability	More on join maintenance
Cost	The poles made of mild steel increase the cost. It is cheaper than design 1.
Aesthetics value	Simple stand

4.4.4 Material Selection

The material used for stand and wood planes of the learning kit will be selected in this section. There are three materials being considered for the stand of the learning kit. In the decision matrix, if an alternatives judged well, it is given a +, if it is poorer it gets a – and if it is about the same it is awarded an S. The material with the most + will be selected. Mild steel is selected as the material used in the fabrication of the learning kit as shown in Table 6.

Table 6: Material Selection

	Alternative 1: Aluminium	Alternative 2: Mild Steel	Alternative 3: Wood
Total length of material used in fabrication	3.42m x 0.05m x 0.02m	3.42m x 0.05m x 0.02m	3.42m x 0.05m x 0.02m
Material cost, RM	RM 450	RM 230	RM 100
Yield Strength, MPa	400	200	33
Material cost	-	+	+
Durability	+	-	-
Weight	+	-	-
Size	S	S	S
Welding cost	-	+	-
Fatigue resistance	+	-	-
Stiffness	-	+	-
Fabrication cost	-	+	+
Total +	3	4	2
Total S	1	1	1
Total -	3	3	4

Mild steel is selected because it ranks highest, especially with regards to the cost. The biggest advantage of mild steel over other materials is that it's rather easy to work with, cheap and high stiffness. Steel is weldable with very cheap tools and reasonably easy to cut. The welding cost of aluminium is expensive due to a more specialized process and advance tools are required if compared with mild steel. The wood planes will be made of wood due to limited budget.

4.4.5 Details Design

The details design can be viewed from various views and it includes the detail dimensional of the stand and wood plane. The detail drawings of the design are shown in Figure 24 (All units are in cm).

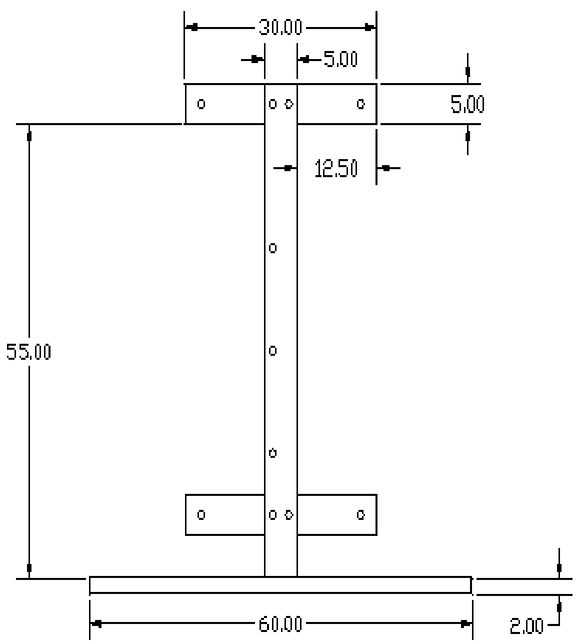


Figure 24(a): Side View

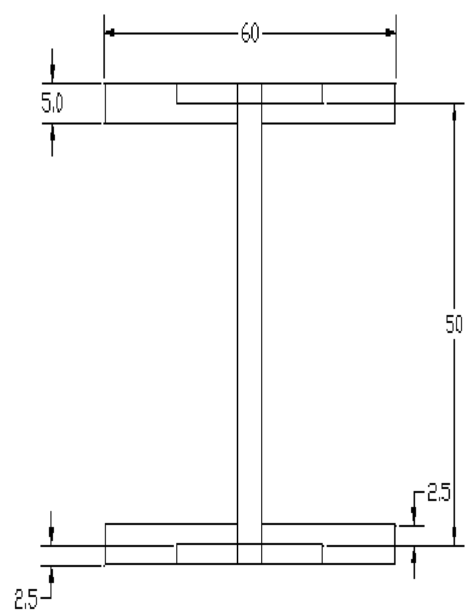


Figure 24(b): Top View

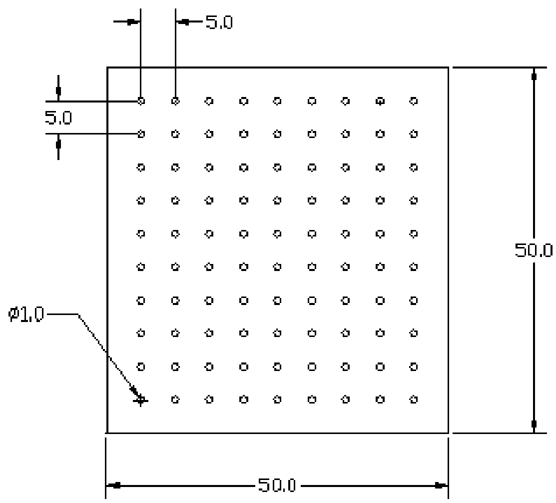


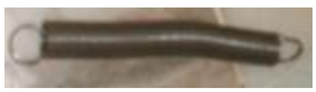
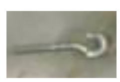
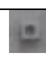
Figure 24(c): Wood Plane

4.4.6 The Model and Parts Functions of the Learning Kit

The parts functions of the learning kit are shown in Table 7.

Table 7: Parts function

No.	Parts	Functions
1	Rings 	To attach ropes from different direction.
2	Rope 	To connect between pulley and weight or to knot the calibration weights as hanger
3	Calibration weights of 20g, 50g, 100g and 400g	To suspend on bridge segment or end of the rope to enable various setting.

	 	
4	Pulleys 	To change the direction of an applied force, transmit rotational motion, or realize a mechanical advantage in either a linear or rotational system of motion.
5	Coil springs 	To store mechanical energy and demonstrate spring elongation.
6	Steel beam (length ≈ 31.50cm) 	Suspend different calibration weights to calculate for moment and equilibrium condition.
7	Hooks (Ø = 5mm) 	To attach rope to the wood plane
8	Nuts (Ø = 3mm)  & 	To fasten the hooks.
9	Protractor (180º & 360º)  	To measure angle
10	Measuring Tape 	To measure length of the rope or the hole between wood plane.
11	Screw (length: 7cm) 	To attach protractor (360º)
12	Screw (length: 26cm)	As a support for a rigid body subjected to

		three dimensional force system
13	"L" bracket 	As support in calculating force system resultants in setting 5.

4.4.7 Bill of Material

The bill of material of the learning kit is shown in Table 8 and the assembly drawing of the learning kit is shown in figure 25.

Table 8: Bill of materials

No.	Parts	Quantity	Material	Dimensional (cm)
1	Top wood plane	1	wood	50 x 50 x 0.12
2	Back wood plane	1	wood	50 x 50 x 0.12
3	Bottom wood plane	1	wood	50 x 50 x 0.12
4	Vertical stand	2	Steel	60 x 5 x 2.5
5	Base steel	2	Steel	60 x 5 x 2.5
6	Connector steel	1	Steel	50 x 5 x 2.5
7	Side steel	8	Steel	22.5 x 5 x 2.5
8	Bolt	16	Steel	M5 x 0.5

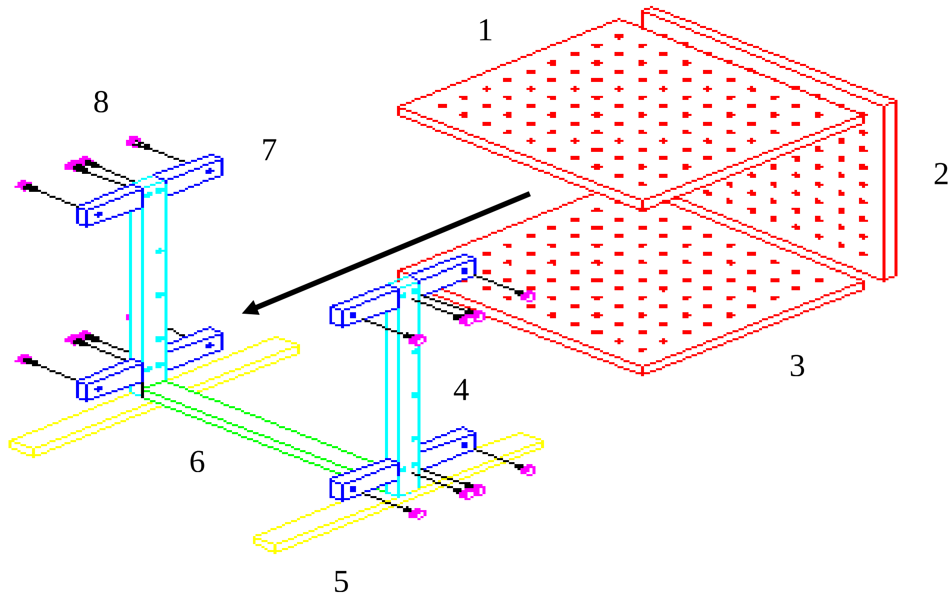


Figure 25: Assembly Drawing

Specifications of other parts of learning kit are shown in Table 9.

Table 9: Specifications of other parts

No.	Other Parts	Quantity	Material
1	Rings	2	Iron
2	Rope	1	Fiber
3	Calibration weights of 20g, 50g, 100g and 400g	6	Steel
4	Pulleys	6	Iron
5	Coil springs	1	Iron
6	Steel beam (length ≈ 31.50cm)	3	Steel
7	Nuts (Ø = 3mm)	10	Steel
8	Protractor (180º & 360º)	2	Plastic
9	Hooks (Ø = 5mm)	6	Iron
10	Measuring Tape	1	Plastic & Steel

11	Screw (length: 7cm)	1	Steel
12	Screw (length: 26cm)	1	Steel
13	"L" bracket	1	Iron

4.4.8 Model and Objectives of settings for learning kit

The model of learning is illustrated in Figure 26 as shown below.

Figure 26: The model of learning kit (front view & side view)

The objectives of the Settings are shown in Table 10. The model of the learning kit can provide eleven settings/experiments as well as demonstrations. Refer to Appendix E for the equipments needed, procedure and question and calculations in different settings.

Table 10: Objective of the settings

No. of Settings	Chapters	Objectives
1.	Force vector (2D)	To show how to add forces and resolve them into components by using Parallelogram law. After performing this learning kit, students should be able to do the following: ▪ Understand addition of a system of coplanar forces. ▪ Apply the Pythagorean Theorem and calculate direction angle.
2.	Force vector (3D)	To express force and position in Cartesian vector form. After performing this learning kit, students should be able to do the following: ▪ Understand force vector directed along a line. ▪ Calculate unit vector and determine position vector.
3.	Equilibri-um of a Particle (2D)	To introduce the concept of the free-body diagram of a particle and solve the particle equilibrium problems using the equation of equilibrium. After performing this learning kit, students should be able to do the following: ▪ Comprehend on Hooke law. ▪ Draw the free body diagram. ▪ Understand clearly on coplanar force system.
4.	Equilibri-um of a Particle (3D)	To show how to solve particle equilibrium problems using the equations of equilibrium. After performing this learning kit, students should be able to do the following: ▪ Draw the free-body diagram. ▪ Solve three-dimensional force system. ▪ Understand clearly on Hooke law.

5.	Force system resultant	To show the principle of moment that is the moment of a force about a point is equal to the sum of the moment of the force's components about the point. After performing this learning kit, students should be able to do the following: ▪ Use scalar analysis or vector analysis to determine the moment of the force.
6.	Further reduction of a force	To show resultant force $F_R = \sum F$ and resultant couple moment $M_{Ro} = \sum Mo$, which are perpendicular to one another. After performing this learning kit, students should be able to do the following: ▪ Comprehend on concurrent force systems and coplanar force system. ▪ Understand on force summation and moment summation.
7. & 8.	Equilibrium of a rigid body (2D)	To show how to solve rigid body equilibrium problems using the equation of equilibrium and assist student in develop the equations of equilibrium for a rigid body. After performing this learning kit, students should be able to do the following: ▪ How to draw a free-body diagram for equilibrium in two dimensions. ▪ Understand on support reactions on hinge subjected to two-dimensional force system and how to use the equation of equilibrium.
9.	Equilibrium of a rigid body (3D)	To introduce the concept of the free body diagram for a rigid body and to show how to solve rigid body equilibrium problems using the equation of equilibrium. After performing this learning kit, students should be able to do the following: ▪ How to draw a free-body diagram for equilibrium in three

		dimensions. ▪ Understand on support reactions on ball and socket joint subjected to three-dimensional force system and how to use the equation of equilibrium.
10.	Force Table	To demonstrate that a system in equilibrium has no net force on it that is the vector sum of the forces must be zero. After performing this learning kit, students should be able to do the following: ▪ Understand that the vector sum of all the individual forces must add up to zero. ▪ The true condition for static equilibrium is that Σ Fx = 0; Σ Fy = 0.
11.	Torque in different direction	To show that the (vector) sums of the torques acting on the body are zero. After performing this learning kit, students should be able to do the following: ▪ Understand that the sum of the counterclockwise torques is equal to the sum of the clockwise torques. ▪ Torque or moment of force is equal to lever arm multiple by force.

4.5 Engineering Design Analysis

4.5.1 Calculation of Shear Stress Acting on Screw

The wood plane shown in Figure 27 is suspended from a 5mm diameter screw, which is fastened to the mild steel and wood plane. There are eights screw fastened to the wood plane (2kg). The screw can withstand the shear stress up to 200 MPa. The calculation on shear stress is shown below.

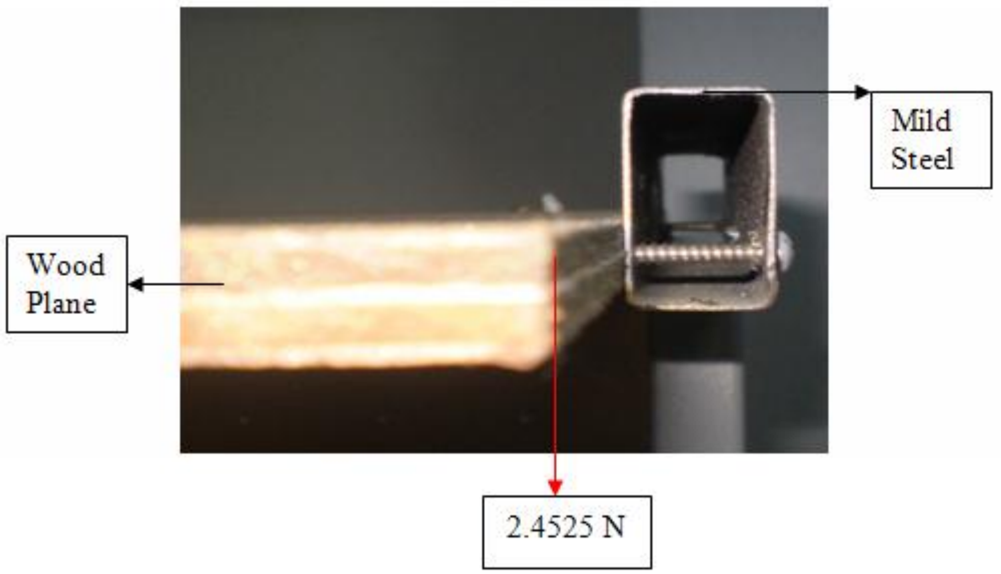


Figure 27: Shear stress acting on screw

$\tau = V/A$;

Where τ = shear stress at the section

V = internal resultant shear force at the section

A = area at the section

V = (2 x 9.81)/8 = 2.4525 N (average shear force acting on each screw)

$A = \pi\ (0.0025^2) = 1.96 \times 10^{-5}$

$\tau = 2.4528/\ (1.96 \times 10^{-5}) = 125$kPa (this value wouldn't causes any failure to the screw)

4.5.2 Calculation on Shear and Bending Moment

Assume that the load of wood plane B and C are subjected to wood plane A where each wood plane consists of 2kg weight (Figure 28). The concentrated force is assumed to be 6.87 N (the total weight of the learning kit's equipments such as weights, springs and pulleys). The shear and moment diagram are constructed as in Figure 29.

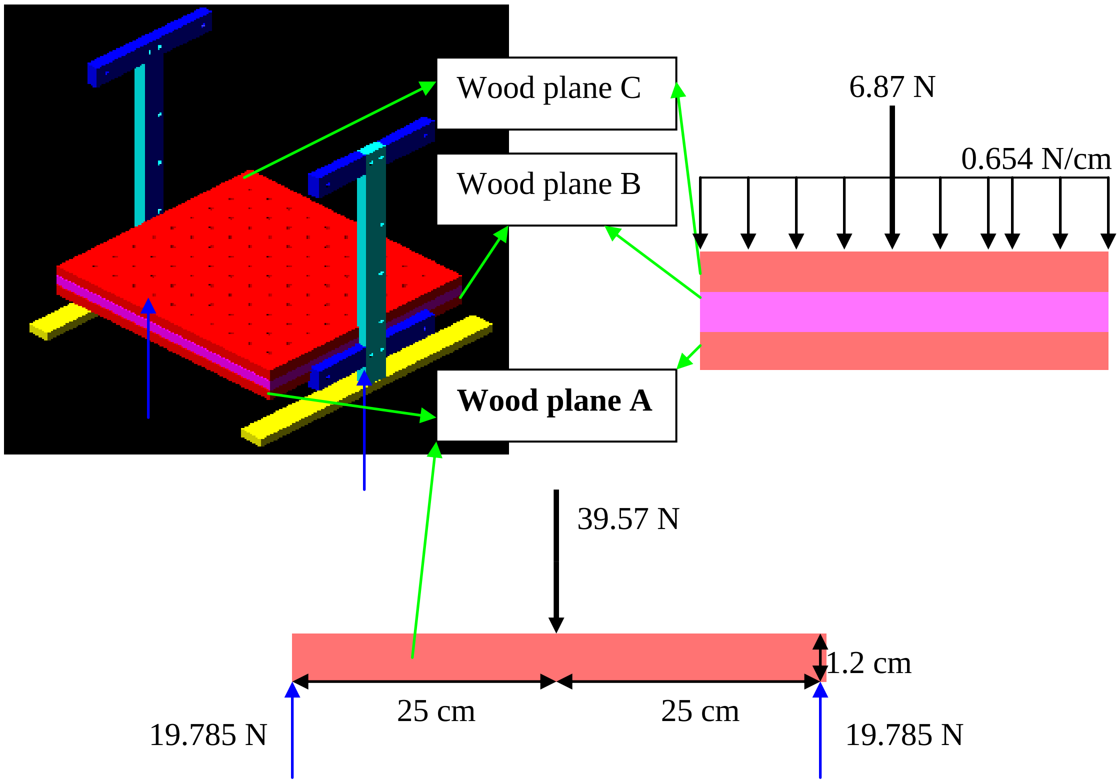


Figure 28: Free body diagram

The total of wood plane B and C subjected to wood plane A = 4kg

Distributed load = (4kg x 9.81)/ (50cm x 1.2cm) = 0.654 N/cm

Total concentrated force = 6.87 + (0.654 x 50) = 39.57 N

V = 19.785 N

M + 39.57(X – 0.25m) – 19.785X = 0

M + 39.57X – 19.785X – 9.8925 = 0

M = 9.8925 – 19.785X

X = 0.25m; M = 4.946 Nm

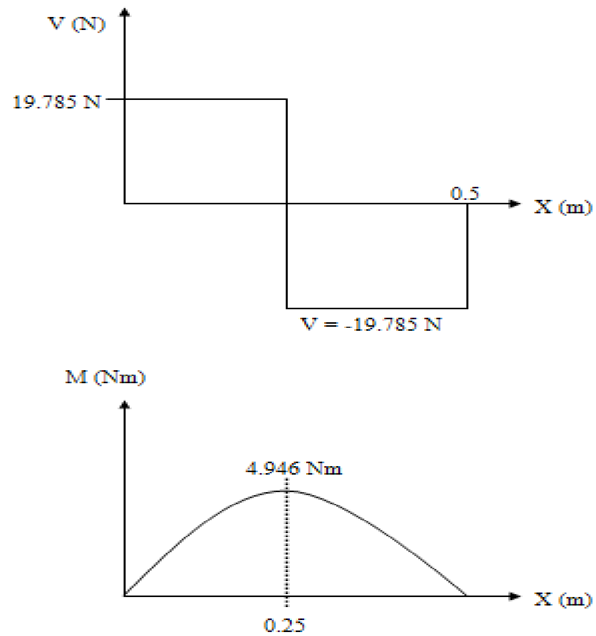


Figure 29: Shear and bending moment diagram

4.5.3 Bending Stress and Shear Stress

The wood plane A is subjected to the stress distribution as shown in Figure 30. Below is the calculation of bending stress.

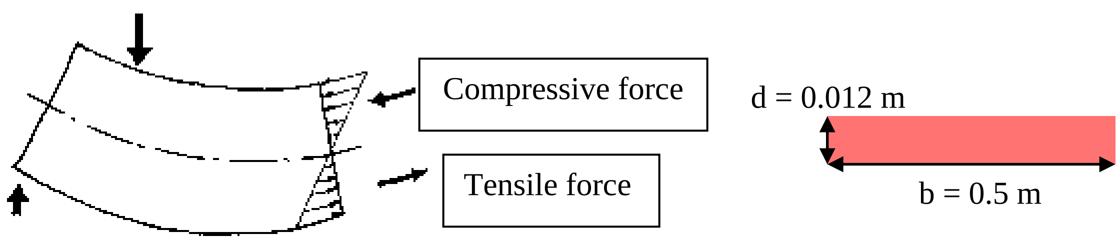


Figure 30: Bending stress

$\sigma = Mc / I$

Where σ = the normal stress

M = the resultant internal moment

I = the moment of inertia

c = the perpendicular distance from the neutral axis

Moment of inertia, I = (1/12)*(bd^3) = (1/12)*(0.5)*(0.012^3) = 7.2 x 10^{-8} m^4

Bending stress σ = (4.946*0.006) / (7.2 x 10^{-8}) = 412.167 kPa

The wood plane A is subjected to a shear force V = 39.57 N as shown in Figure 31. The calculation on shear stress is shown below.

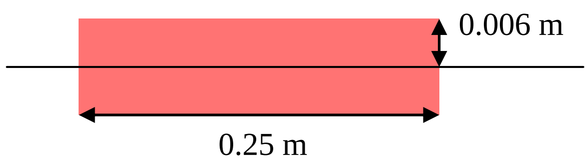


Figure 31: Shear stress

τ = VQ/It;

Where τ = shear stress

V = internal resultant shear force

Q = statical moment of area

I = moment of inertia

t = the width of the member's cross-sectional area

Q = (0.006 / 2)*(0.5)*(0.006) = 9 x 10^{-6} m^3

τ = {(39.57)(9 x 10^{-6})}/{(7.2 x 10^{-8} m^4)(0.5)} = 9.89 kPa

4.5.4 Deflection of the learning kit

Below is the calculation on deflection of the learning.

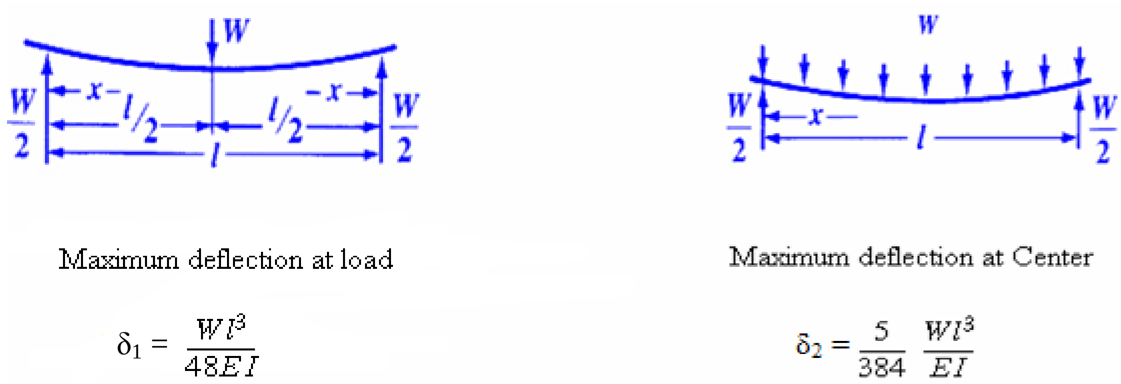


Figure 32: Formula of the deflection

Where W = load

l = distance

E = modulus of elasticity

I = moment of inertia

$\delta_1 = \{(6.87)(0.5^3)\} / \{(48)(10 \times 10^9)(7.2 \times 10^{-8}\ m^4)\} = 2.5 \times 10^{-5}$ m

= 0.025mm

$\delta_2 = \{(5)(32.7)(0.5^3)\} / \{(384)(10 \times 10^9)(7.2 \times 10^{-8}\ m^4)\} = 7.4 \times 10^{-5}$ m

= 0.074mm

Deflection = $\delta_1 + \delta_2$ = 0.025 + 0.074 = 0.01mm (proved that the learning kit has a excellent stability)

4.5.5 ANSYS

The figure 33 and 34 demonstrate the stress analysis and stress distribution on learning kit stand in setting of 3D experiment. In node A, the maximum stress is 26.233MPa and the minimum stress is 1.56Pa as shown in the Figure 33.

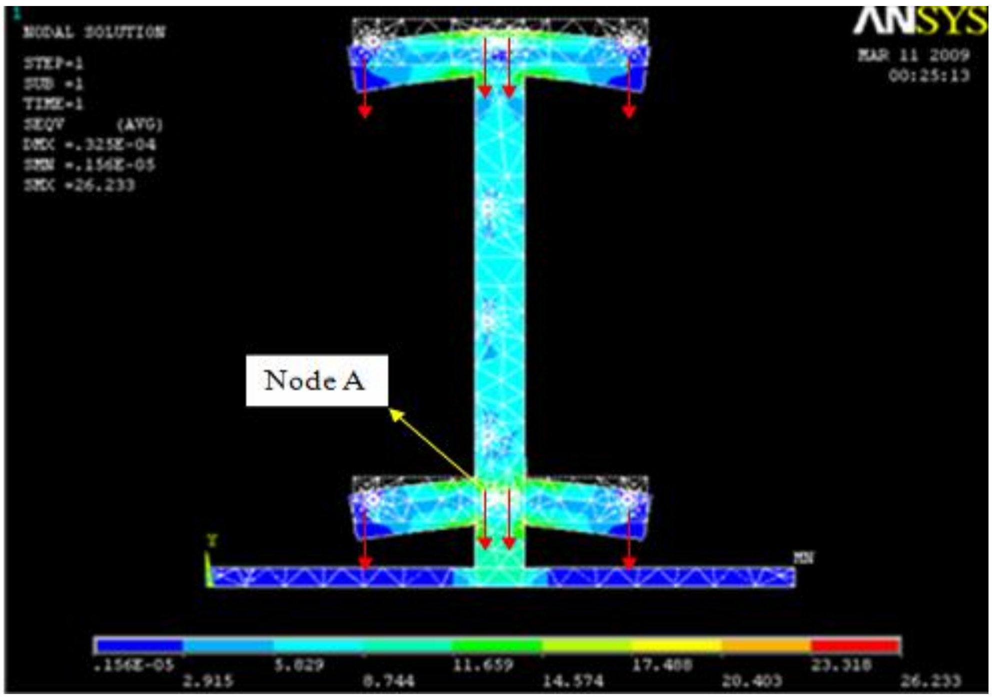


Figure 33: Stress analysis on learning kit stand in setting of 3D experiment

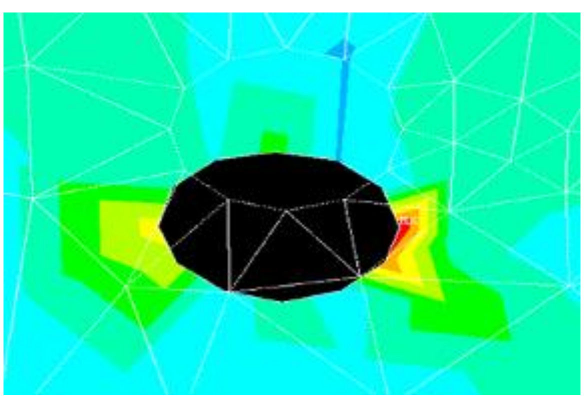


Figure 34: Stress distribution on node A

The figure 35 and 36 demonstrate the stress analysis and stress distribution on learning kit stand in setting of 2D experiment. In node B, the maximum stress is 16.562MPa and the minimum stress is 0.308Pa as shown in figure 35.

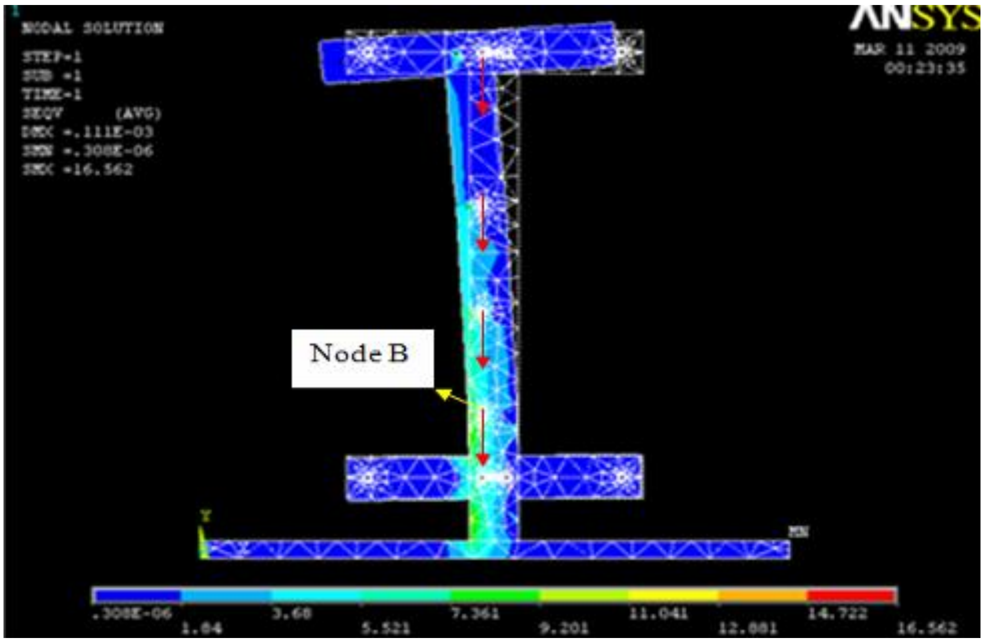


Figure 35: Stress analysis on learning kit stand in setting of 2D experiment

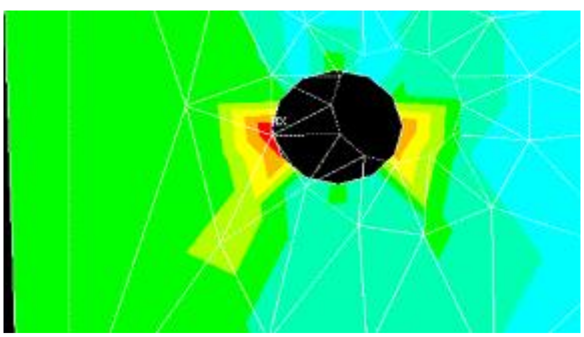


Figure 36: Stress distribution on node

4.6 Test and Validation

The test and validation is done to the model of the learning kit. One student (Amiruddin Bin Mohaini, ID: 11437) is selected in batch Jan 2009 who failed in Statics

Final Examination July 2008 to test the effectiveness of the learning kit. Two tests are conducted to the student (Appendix F: Test questions). Test 1 is conducted before hands-on the model of the learning kit while test 2 is conducted after hands-on the learning kit. (Appendix G: Student's solution to the tests). The tests result is shown in Figure 37.

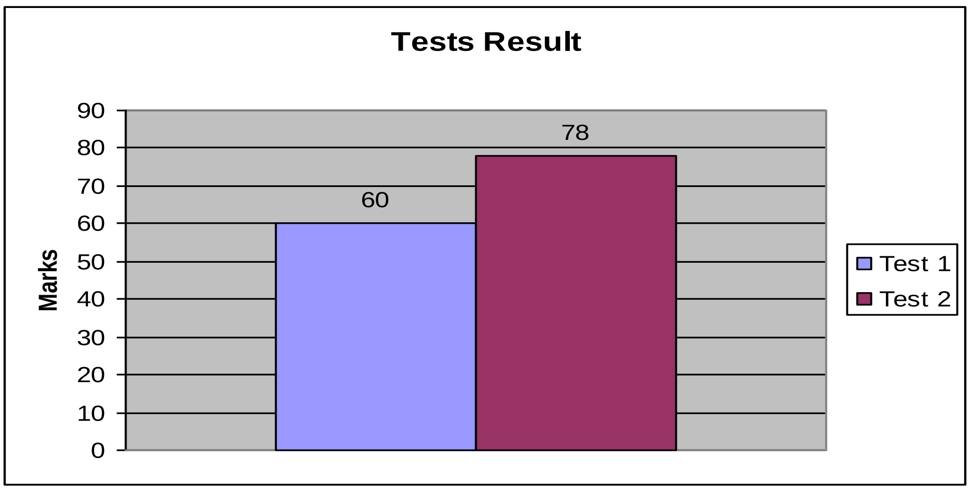


Figure 37: Tests result

From the histogram, the participant obtained 60 and 78 out of 100 marks in test 1 and test 2 respectively. By comparing test 1 and test2, the marks of the tests has been increased up to 30%. This is because the model of the learning enables student to have better understanding in learning Statics. As a conclusion, the tests result shown that the model of the learning kit is effectiveness and can assist student to abstract concept in learning Statics

CHAPTER 5
CONCLUSION

The application of Statics is widely applied in engineering field such as architectural and structural engineering. For example, students need to have strong fundamental of structural analysis is required in order to design of a bridge truss. Moreover, design of a cart lift, pulley system, a tool used to position a suspended load, a tool used to turn plastic pipe and fence-post remover require the knowledge of Statics.
Hence, it is importance for students to comprehend well in learning Statics so that they will not be lagged behind or quitting the engineering program out of frustration. Based on Kolb's learning style and Kolb's cycle, learning kit is useful for converging and accommodating learner to abstract ideas, formulate problems and learn more effectively. Also, according to Kolb's cycle, physical interaction of students with the material will enhance students' understanding in that particular subject. Hence, a learning kit for Statics is introduced since it enables students to have better understanding in the fundamental of Statics. It can provide eleven settings/experiments and demonstrations. The settings cover the chapters of force vector, equilibrium of a particle, force system resultants, equilibrium of a rigid body, force table and torque in different direction.

Recommendation

Although the objectives of this project have been achieved, there are some recommendations can be made to improve the effectiveness of the learning kit. To enhance students' understand in learning Statics, the settings of the learning kit need to be increased. A lot of researches still need to be done in progress to understand students' problems in learning Statics. This is because students' problems can be varies from time to time. To improve the design of the learning kit, comprehend students' problems in learning Statics is very crucial.

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