COGNITIVE TOOL: LEARNING FORCES FOR BEGINNERS

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Special thanks to my husband, Mustaffa Mat Arof, family and other fellow coursemates for providing their unfaltering support thought all the years. To my children, Ahmad Adib and Adiba Auni, thank you for understanding me and being supportive all the way through. Without them, I wouldn't have made this a reality.

Abstract

Many subjects taught in school are supported by CAI software. Learning about forces is difficult if it is learned theoretically. Students fail to understand the basic concept of forces, therefore they generalize that learning physics is difficult. The purpose of this research is to develop a prototype that can make learning physics fun and easy. The tool guides students to identify and draw forces acting on objects and visualize the motions. Lessons, questions and learning activities are provided, supported with animated examples. Students are guided through problem so as to relate the ideas to be learnt to those acquired earlier. Results show that they learned and understand the concept better.

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Chapter 1

Introduction

Many students progress through kindergarten, primary school, secondary school and higher institution without learning how to reason or think for themselves. Traditional methods of instruction that have been used to educate these students are basically giving them chunks of material. They are expected to reproduce the materials during tests and assessments. Their progress is assessed by the amount of the material they have been able to retain and reproduce on demand. As a result, many of them leave schools with the impression that learning is merely as memorization of fact.

The purpose of this dissertation is to develop a prototype that can help students in constructing their understanding of the basic concept of forces. Normally, students are expected to be able to visualize the motion from problems given in class. But the reality is that without understanding of the concepts, they are unable to do it. They need to be guided to improve their problem solving skill.

To mechanics, students are initially taught the concepts before applying them to solve problems. Misconceptions are often related closely to daily experience with real events. The inherent misconceptions cause difficulties in problem solving. It is crucial for students to have strong foundations in various concepts. They need to acquire the correct concept about forces before they can learn more advance topics.

A cognitive tool is proposed to develop students' ability to solve the above problems. It is named FORPHY (Learning Forces in Physic – for beginners). The tool stimulates students' thinking in order to understand the basic concept of forces by promoting thinking.

1.1 Research aims and objectives

The aim of this project is to enhance the students' understanding about force. The proposed tool, FORPHY will highly encourage learning activities. This has been done for the following reasons:

- Overcoming difficulties in learning physics

  Students are unable to link the abstract formalization of physics to their real world counterparts. McDermott (1993) describes difficulties in three areas

  - Algebraic representation
  - Diagrammatic representation
  - Graphical representation
- Developing problem solving skills

  Students need to develop a well-organized, meaningful set of knowledge. This helps in the development of problem solving skills.
- improving creative thinking and problem solving skills via drawing

  Students can learn to visualize through drawing so that they can portray the problem in drawing effectively.

The specific objectives are:

- To develop a prototype for a cognitive tool to learn about force.
- To improve students' ability in identifying concepts of forces.

- To create a cognitive tool to help students overcome the difficulties in learning forces.
- To provide animated diagram for the understanding of forces.
- To study difficulties in learning forces

FORPHY is designed specifically to overcome the difficulties students faced in learning forces. The prototype tests on the students' understanding on forces and skills developed. It is supported by animated diagram which can enhance further understanding. It helps teachers to sharpen students' ability to differentiate forces and useful as complementary tool in class.

1.2 Scope

The prototype is designed to introduce a concept of learning forces in physics for the beginners' level. It covers all types of forces which can be introduced in the secondary schools. The system scope is based on lessons provided using animation, allowing users the opportunity to experience the idea discussed. Exercises are given at the end of each lesson. The exercises allow students to run the animation, draw arrows that represent the direction of force, drag and drop the correct label type of force.

The system does not provide any grades or comments. The lessons show the effect of forces on objects. The exercises require students to name the correct forces and know the direction of forces. It also projects the effects of the forces chosen when applied to certain objects.

1.3 Motivation

A significant portion of students taking physics course in secondary schools and higher level institutions have difficulty in learning physics. Some of the difficulties have been attributed to problem solving. Students are unable to identify and differentiate the different types of forces. Often explanations from textbooks and tutors are insufficient.

Problems in physics can be modeled or represented by pictures, graphs and diagrams. Many problems in the physic course can be described with a drawing. Drawings help students to reason qualitatively when solving problem, which helps them to enhance their knowledge. This is the main reason why students should learn how to recognize each force and draw them correctly in learning the concepts and their relations.

1.4 Problem Definition

Misconceptions in forces originate from difficulties in relating real situation with theories taught in class. Despite the use of diagrams for explanation, students are still unable to visualize the problem. Often they are unable to even start drawing the correct diagram because they failed to identify the type of forces acting on the objects.

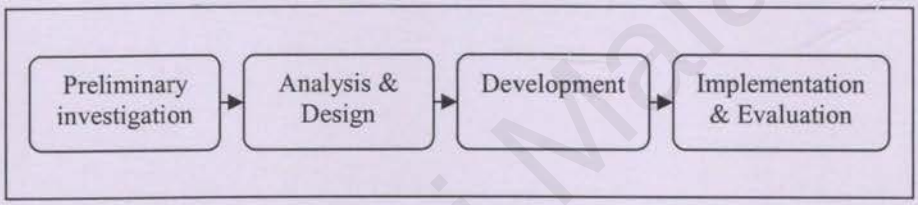
If they are given a problem and required to draw a free-body-diagram, they could not do it correctly. They have many misconceptions about force. Consider the statement. "A ball is moving, therefore it must have force acting on it." Usually students think that this is true. The misconception here is that "motion implies a net force". Students think there must be a

force keeping it moving. Not many students realized that the existence of force implies that there is acceleration. It is momentum that keeps the ball going but momentum is not a force. Sometimes, students are unable to identify the number of forces and their direction. As a result their incorrect drawing does not represent the problem situation, which leads to incorrect 'solution'.

1.5 Methodology

The course of action taken in carrying out this thesis is depicted in Figure 1.1.

Figure 1.1: Overall Research Process



The research applies the Problem Based Learning (PBL), a constructivism approach introduced in traditional learning at McMaster University, Canada (Barrow & Tamblyn, 1980). A problem is given and students construct steps to solve it.

At the early stage, investigation is done to find out the difficulties that normally arise when students start to learn forces. These difficulties are taken into consideration before designing the tool.

Important elements are analyzed and designed for the tool development requirement such as learning approach, topic discuss, animations and learning activities. Implementation emphasizes on how the elements included in the system by using several application software available.

A small number of secondary school students are chosen to test FORPHY. They are given a questionnaire which is used to evaluate the effectiveness of the prototype. The questionnaire designed focuses on the learning ability and the understanding of the concept of force.

Chapter 2

Learning Forces in Physics

Physics is the study of motion, matter, energy, and force. When people start questioning why does it happen or how does it work, this lead them into the world of physics if they scrutinize the answer. This leads to the discovery of laws and theories such as the gas laws, Newton's Law of Gravity etc. Learning physics, normally begins with the study of motion, introducing the concept of velocity, acceleration, force, mass, energy and momentum.

2.1 Forces

A force may be a push or a pull as a result of an object's interaction with another object. A force can slow down an object, stop its motion or change the direction of an object's motion. The heavier the object is, the bigger the force required to accelerate or to decelerate it. Interaction between two objects implies the existence of force acting on object.

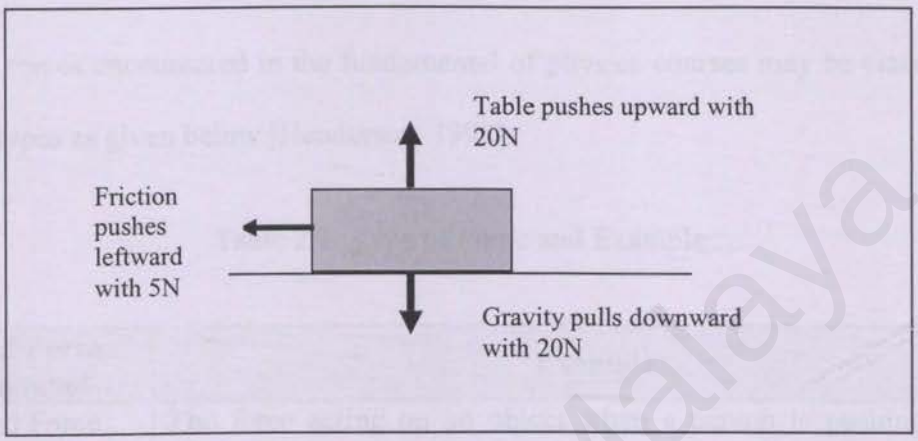
Force is measured in Newton (N).

$$1 \text{ Newton} = 1 \text{ kg} * \text{m/s}^2$$

Force has both magnitude and direction, i.e. it is a vector quantity. It is common to represent forces using arrows. This pictorial or graphic representation helps student to

understand the concept better than textual or verbal presentation. The size and the direction of the arrow indicate the magnitude and the direction of the force respectively. Figure 2.1 illustrates forces acting on a block.

Figure 2.1: Forces Representation



2.2 Direction of Force

If a moving object is given a push in a direction at an angle to the direction the object is traveling, the motion changes direction. For example, if one person pulls on a rope with a force of 15 N and another person pulls in the opposite direction with a force of 12 N, the total force will be 3 N in the direction of the 15 N force.

2.3 Classes of Forces

Forces can be categorized into two classes:

- Contact Force

  The forces act by direct contact, such as when we push a table or move a book from a table. Example of contact forces: Frictional Forces, Tensional Forces, Normal Forces, Air Resistance, Applied Forces and Spring Forces.

- Action-at-a-distance Forces.

  Forces of two interacting objects that are not in contact physically. Example: Gravitational Forces, Electrical Forces and Magnetic Forces.

2.4 Types of Forces

Common forces encountered in the fundamental of physics courses may be classified into different types as given below [Henderson, 1998]:

Table 2.1: Type of Force and Example

Type of Force And symbol	Example
Applied Force F_{app}	The force acting on an object when a person is pushing a desk across the room.
Gravity Force (also know as Weight) F_{grav}	All objects upon earth experience a force of gravity which is directed "downward" towards the center of the earth.
Normal Force F_{norm}	The force acting on an object when If a book is resting upon a surface, them the surface is exerting an upward force upon the book in order to support the weight of the book.
Frictional Force F_{frict}	The force acting on a book moves when it across the surface of a desk in the opposite direction of its motion.
Air Resistance Force F_{air}	A skydiver or a downhill skier which travel at high speeds.
Tensional Force F_{tens}	The force, which is transmitted through a string, rope, or wire when it is pulled tight by, forces acting from each end. The tensional force is directed along the wire and pulls equally on the objects on either end of the wire.
Spring Force F_{spring}	An object, which compressed or stretches a spring, is always acted upon by a force, which restores the object to its rest or equilibrium position.

Chapter 3

Problem Based Learning

Problem Based Learning (PBL) is an effective teaching method in enhancing students' learning skill. It makes learning more enjoyable, motivating and consequently, the information studied is retained better. The primary distinction from other forms of learning is the focus on introducing concepts to students by challenging them to solve problems.

Traditional problem-based examinations are not efficient instruments for assessing the structure of physics students' conceptual knowledge or providing diagnostically detailed feedback to students and teachers. [Beatty et al, 2002] proposed a candidate assessment instrument for exploring the connections between concepts in a student's understanding of a subject. The assessment approach is for eliciting information about students' conceptual knowledge structure.

It is found that students gain understanding well if they had their lecture first before attempting any questions. Although questions drive discussion and motivate short lecture, they still need to understand the concept first. Students apparently learned the material and prepared for examinations by attending revision sessions and trial. Further, students found the lecture sessions that least effective component of the course [Franklin et al, 2001].

3.1 What is Problem Based Learning?

In traditional science class, learning begins with the concept introduced first, followed by an application problem. With Problem Based Learning (PBL), real problems are given to students to experience the concept underlying. Students who acquire scientific knowledge in the context in which it will be used are more likely to retain what they learned and apply the knowledge appropriately [Albanese and Mitchell, 1993].

The learning is more important than the solution of the problem. The problem is analyzed to find out what is needed to know and then applied to the new knowledge. It encourages independent learning and a better understanding of the subject matter.

3.2 The process of PBL

Below are the steps used in PBL

- A problem is presented to students who are grouped in small numbers. Students organize their ideas and previous knowledge related to the problem and attempt to define the broad nature of the problem.
- Throughout discussion, students raise questions on the areas which they do not understand. Students are encouraged to explain what they know and what they do not know. These are known as learning issues.
- Students rank in order of importance the learning issues obtained from the discussion. They decide which issues should be followed up by the whole group and those that can be assigned to individuals, who later teach the rest of the group. The issues are discussed to find out what resources are needed to research the learning issues and where to find them.

- When students reconvene, they explore the previous learning issues, integrating the new knowledge into the problem context. Students are encouraged to summarize their knowledge and connect new concepts to old ones. As learning is an ongoing process, there will always be learning issues to be explored.

3.3 A key factor in PBL

PBL uses problems to motivate, focus and initiate students learning. Therefore, a critical factor in the success of PBL is to focus on the problem itself. A suitable problem would have these characteristics:

- It engages students' interest and motivates them to understand the concepts introduced.
- It requires students to make decision and judgment based on facts, information, logic and rationalization. Students need to justify all decision and reasoning made based on the principles being learned. Problem should require students to define what assumption needed and why certain information and steps or procedures are required to solve them.
- Cooperation from group member is necessary in order to effectively work through a problem.
- The problem should be of the following form
  - Open-ended, not limited to one correct answer
  - Connected to previously learned knowledge
  - Controversial issues that will elicit diverse opinions

- The content objective of the course should be incorporated into the problems, connecting previous knowledge to new concepts.

3.4 Solving a problem.

Students who are able to solve a problem are considered to have understood the subject. Their understandings of the concept are enhanced by applying the concepts in new situations. They may understand the concept but are unable to solve related problem. From the skills obtained, student should feel easier to trace the problem and find the solution effectively.

Consider the situation of a person who wants his life style to be upgraded by having a new car. However his income is only enough for basic expense, leaving very little for savings. So the problem here is how the person can increase his income and achieve his objective that is to buy a new car. The first important step in problem solving is to define the problem. The above example given guides us to differentiate a problem and objective. The key in problem definition lies with the person's ability to differentiate a problem and its symptoms. A well-defined problem is easier to solve. A list of terminology used in problem solving is defined below [Shibata, 1998]. A problem solver should understand the terms in order to avoid confusion before making any decision.

Table 3.1: Terminology in Problem Solving

Term	Definition
Purpose	What we want or need.
Situation	Recognized what circumstances are, as it will help us to narrow down the problem.
Problem	Some portion of a situation is a problem that cannot realize the purpose.

Cause	What brings about a problem. Causes bring about problems, as causes are more specific facts. Finding specific facts which causes problems is the essential step.
Solvable cause	Focus on the solvable cause in order to solve the problem. Solvable causes generated may help in making problem solving efficient.
Issue	The expression of problem. Refer to the example, "has a small income", is a problem, and "increasing the income" is an issue.
Solution	Specific action to solve a problem or to realize the issue.

3.5 Cognitive Tools for Problem Solving

Cognitive tools are the extension of human mental capacity. Simulation Modeling is one of the popular cognitive tools, which facilitate multi decision and problem solving scenarios. When working in everyday situations, individuals use tools and resources such as computers, calculators and formulas to solve problems. Therefore the appropriate tools must be considered when creating comfortable environment for students' learning. Cognitive can help learners organize, restructure and represent information. These tools come in many forms. The tools support students in a variety of tasks they must perform when dealing with problem solving. Computer can be characterized as a tool, which is represented in software like word processors, spreadsheet, databases and drawing applications. In education, it is encouraged to use computers, so that pupils can learn to use these tools in everyday context.

Jonassen and Reeves (1996) have summarized the foundations of cognitive tools research:

- Cognitive tools are most effective when they are applied within constructivist learning environments.

- Cognitive tools empower learners to design their own representations of knowledge rather than absorbing the representation preconceived by others.
- Cognitive tools can promote the deep reflective thinking that is necessary for meaningful learning.
- Cognitive tools enable mindful, challenging learning rather than effortless learning promised but rarely realized by other instructional technologies.
- Cognitive tools should be applied to tasks or problems defined by learners with the support of their teachers.
- Cognitive tools use for education should be situated in realistic contexts with results that are personally meaningful for learners
- Cognitive tools can enable intellectual partnerships in the form of distributed cognitive processing.

A reliable, consistent approach to solving problem using cognitive tools makes it possible for student to:

- Use new concept presented.
- Study the solution of the problems
- Think about the new concept
- Achieve fully understanding of the subject.

This cognitive tool should contain several instructional principles as follows:

- Articulation and reflection: Students have to think about and give reasons for their actions. Students need opportunities to look back over their efforts and analyze their

own performance. If they can solve problems, it can help learners develop more appropriate mental models of expert performance.

- Exploration: Encourage students to try out different strategies and observe their effects. This gives learners practice using their existing knowledge and helps to tie it in with problems in need of solution.
- Sequence: Proceed in an order from simple to complex task. Students are exposed to the underlying principle first, then the application of that principle to specific performance contexts.

Solving problems is a straightforward process requiring:

- Knowledge.

  All knowledge needs to be used, everything from common place daily observations to advanced study of specialized subjects. It may be old knowledge, perhaps from early childhood, or it may be new knowledge encountered today for the first time.

- Rules.

  A few simple rules, easily understood and applied, are used to establish 'where to start' and 'what to do next', in order to produce consistent, reliable solutions.

- Practice.

  No one becomes an expert at anything by just being told how to do it. Consider basketball, golfing, singing, dancing or other favorite skill. Practice must be done correctly in order to be beneficial. So it is with problem solving.

Chapter 4

System Design

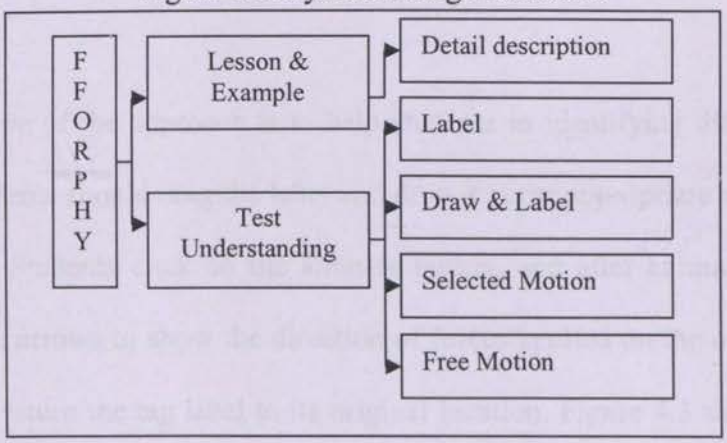
This chapter describes the design structure, screen design, interaction style and feedback of the proposed system. The system consists of two main modules, Lesson & Example and Test Understanding. The screen is designed according to the guidelines from computer based learning and the use of consistent navigational aid. Several types of interaction applied in the system and feedbacks are given for each action taken by the users. A number of samples are given here to present the idea graphically.

4.1 System Design Structure

FORPHY is designed to help students to learn the topic easily. They are given several approaches to try out the exercises to help them acquire the knowledge. Figure 4.1 shows the structure design of FORPHY with the two main modules.

- Lesson & example
- Test understanding

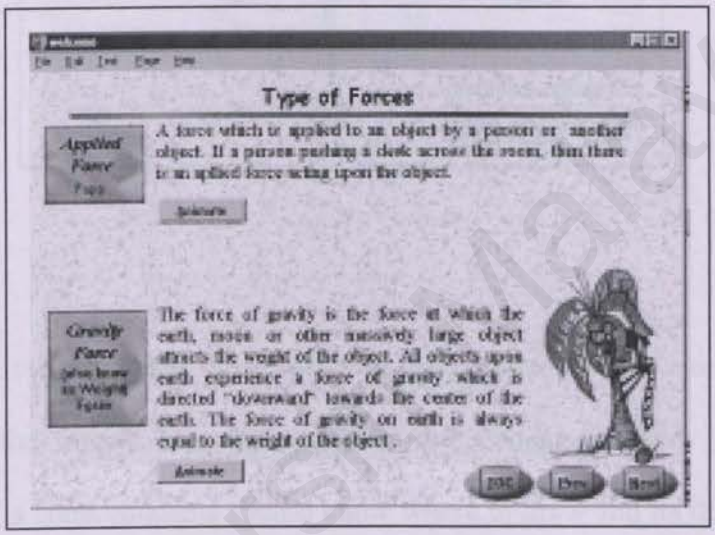
Figure 4.1: System Design Structure



4.1.1 Lesson & Example

The Lesson & Example givens the definition of force, describes the units of measurement used and the representation diagram. Figure 4.2 shows the definitions for two types of forces. A brief definition is supported by animated examples. The animation is activated by clicking on the button.

Figure 4.2: Lesson & Example



4.1.2 Test Understanding

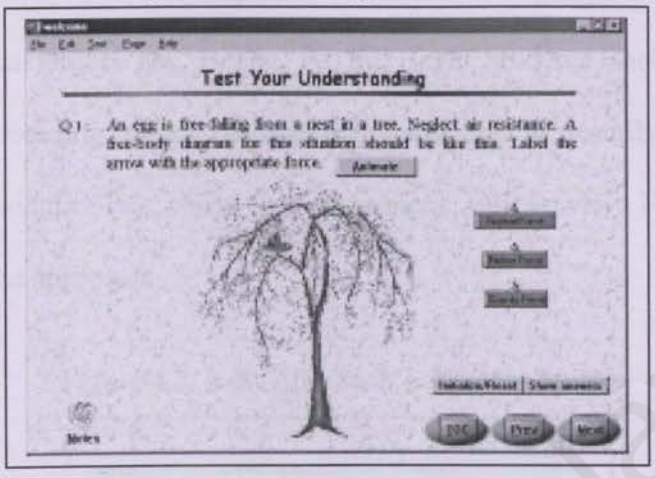
This module provides several questions for the students to test their understanding of various topics using the following approaches.

Label

The objective of the approach is to help students in identifying different types of forces. Students should drag the label and drop it at the appropriate arrow drawn on the screen. Students click on the animate button, and after animation, FORPHY displays the arrows to show the direction of forces applied on the object. Incorrect match will return the tag label to its original location. Figure 4.3 shows the screen

design of the approach.

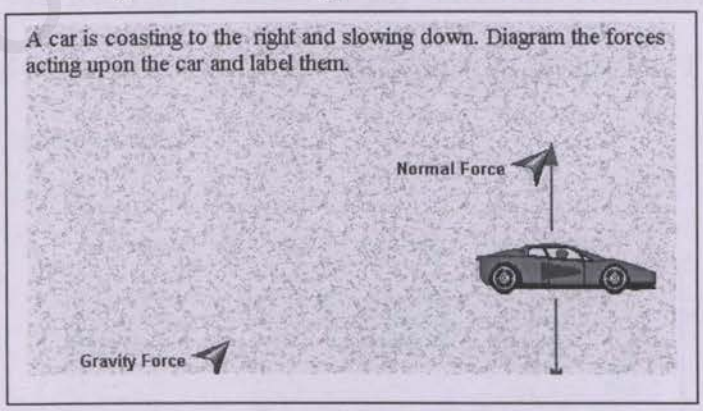
Figure 4.3: Test Approach - Label



Draw & label

The objective is to allow the students to freely draw the direction of arrow which represent the forces. The approach lets the students to draw arrows after the animation is done. Students should know where to draw and its direction. They are also required to name the type of forces the arrow represent. Figure 4.4 shows the design of the approach.

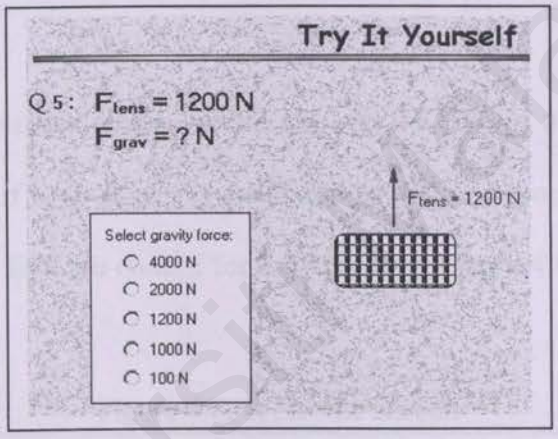
Figure 4.4: Test Approach - Draw & Label



Selected Motion

This exercise allows the students to test the motion produced when a set of forces acting on an object are chosen. At this level students should be able to think logically according to their understanding of forces as described earlier in lesson & example module. The object has its weight and gravity. Figure 4.5 shows the design of the approach.

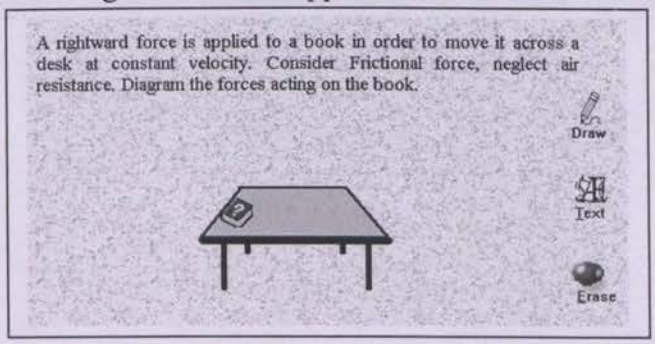
Figure 4.5: Test Approach - Selected Motion



Free motion

This activity helps students to think about the cause and effect of the applied forces. Students can freely draw forces of any directions. Animation is then produced accordingly. Students should try to make sense of the motion. Figure 4.6 shows the design of the approach.

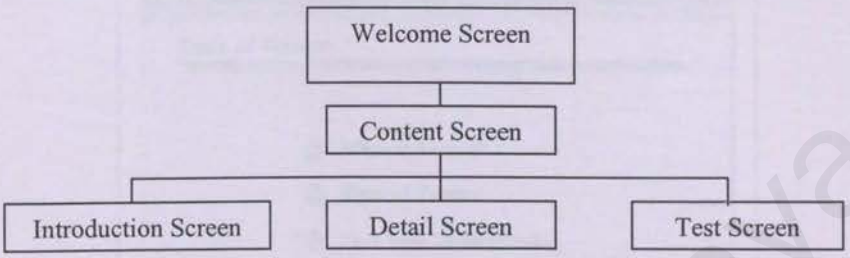
Figure 4.6: Test Approach - Free Motion



4.2 Screen

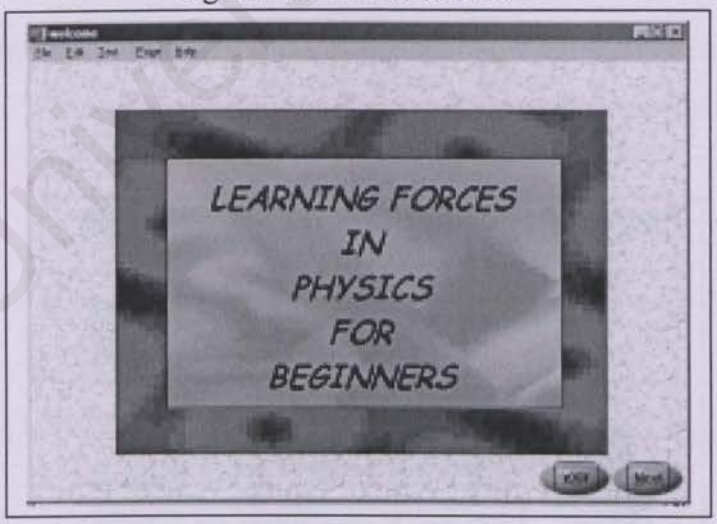
The screen structure of the system is almost similar to a chapter organization. Figure 4.7 shows the hierarchy of the screen.

Figure 4.7: Screen Hierarchy



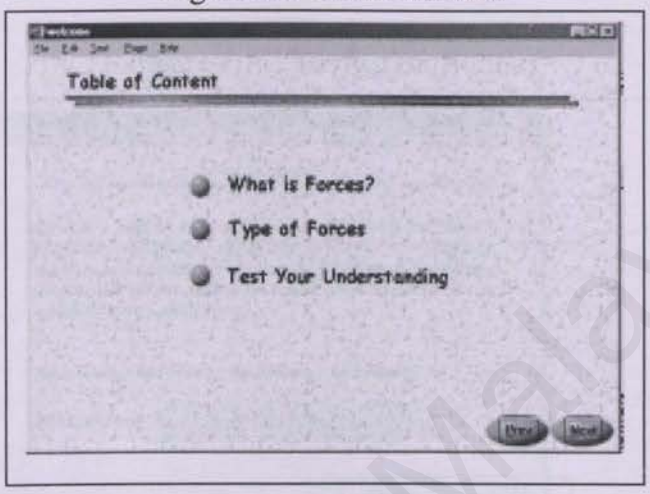
The first screen is a welcome screen, which displays the title of the system at the center. The background color of each screen is standardized and its color is lighter than the text color. The text size and font are chosen for easy reading. Figure 4.8 shows the example of the welcome screen.

Figure 4.8: Welcome Screen



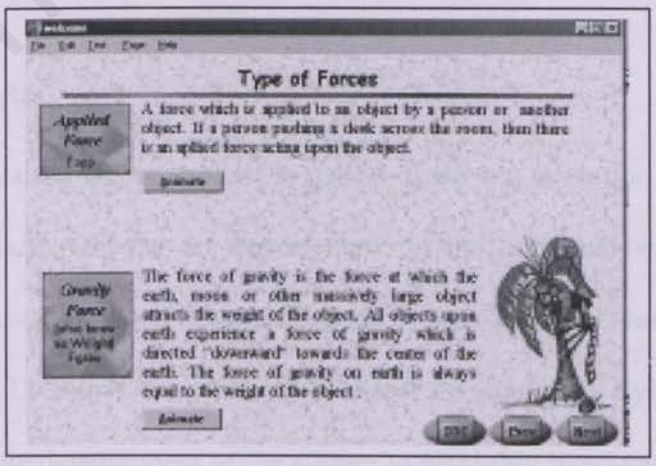
The content screen contains a list of subtopic that is covered in learning force. As the learners see the screen, they can get the overview of the subtopics that they are going to learn, i.e. they can view the contents of the lesson generally (See Figure 4.9).

Figure 4.9: Content Screen



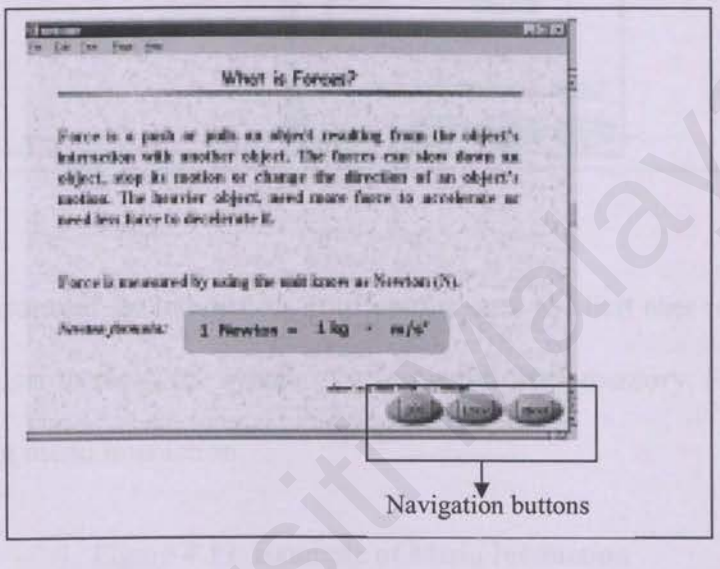
The introduction screen gives the definition of force, units of measurement used and the representation diagram. The next screen displays the details of the topics including animated example. The animation is activated by clicking the button that is located at the end of each description. Figure 4.10 is the example of how the texts are organized.

Figure 4.10:Text Organization



For every screen, the navigation buttons are placed at the bottom right-hand side because they are usually used as the last action taken by the learners. This follows the rules of human natural way of reading text from left to right and line by line from top to bottom. Figure 4.11 shows the location of navigation buttons.

Figure 4.11: Navigation Buttons

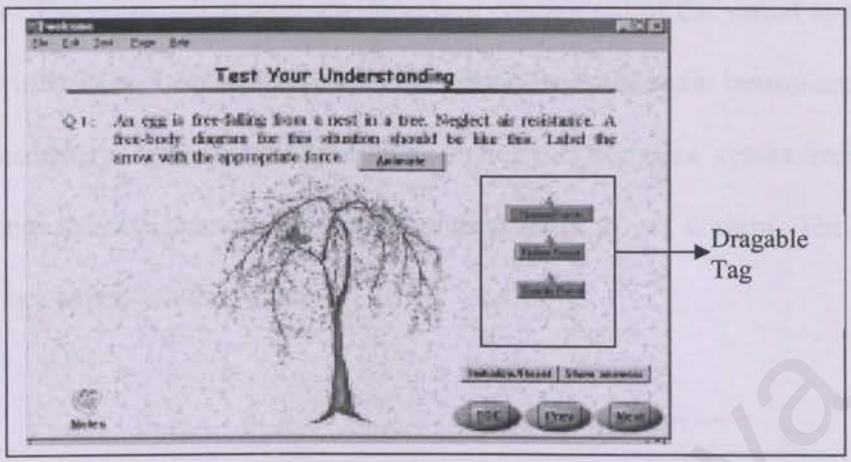


The test screen places the questions at the top of the screen. Animation is added to some of questions where relevant. Figure 4.3, 4.4, 4.5 and 4.6 are the test samples.

4.3 Interaction Styles

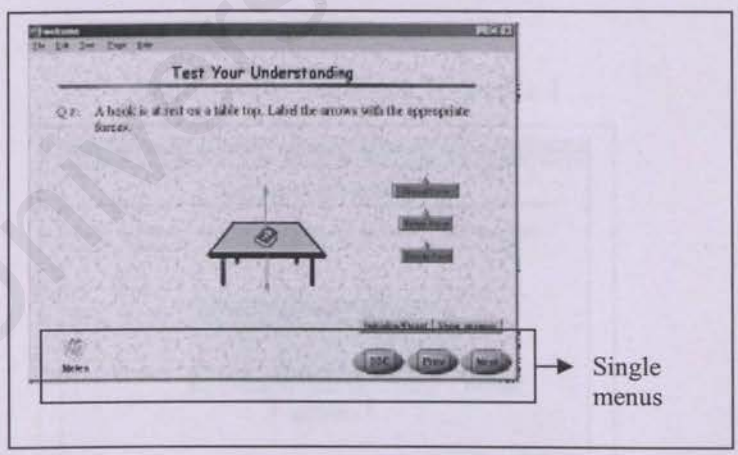
The interaction style used in the system is called direct manipulation or also known as graphical user interface. Objects are represented on the computer screen, and can be manipulated by the user in many ways analogous to how the user would manipulate the real object. Figure 4.12 shows the example of direct manipulation styles. Drag and drop functionality allows the development of the system to be highly interactive application.

Figure 4.12: Example of Direct Manipulation



The menus are also used for interaction. It offers the cues to elicit user recognition, rather than forcing the user to recall the syntax of a command from memory. Figure 4.13 shows the example of the menu interaction.

Figure 4.13: Example of Menu Interaction



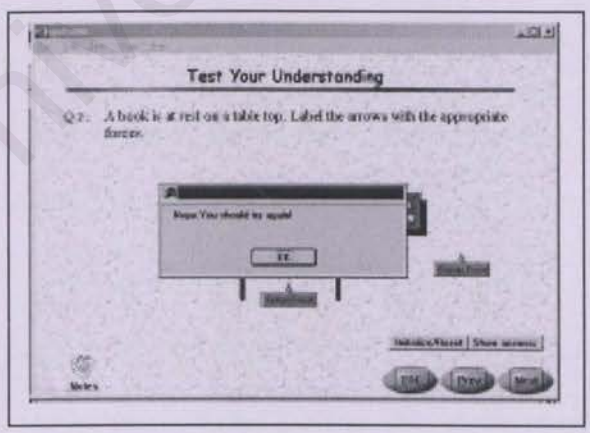
Learners indicate their choices with a pointing device or keystroke and get feedback indicating what they have done. This interaction style helps users to navigate the system quickly. The above example of menu interactions is classified as a 'single menu', meaning

that they do not have any submenus. Most of the menus are shown graphically such as note, draw, etc. These are called icon, an important component of the visual appearance of graphical user interfaces. Learners may click an option from the radio button and the effect is shown immediately. These interaction style, instead of complex syntax reduce errors. For the drawing activity, learners may need several trials to get it right. The inaccurate drawings will not appear on the screen.

4.4 Feedback

Feedback is one of the important elements in the system because it motivates users or learners to participate actively in the learning process. In the test understanding section, the feedback is prompted after the users' action. The purpose of this feedback is to give users the opportunity to consider information about the suitability of their response. Figure 4.14 shows one of the feedback examples.

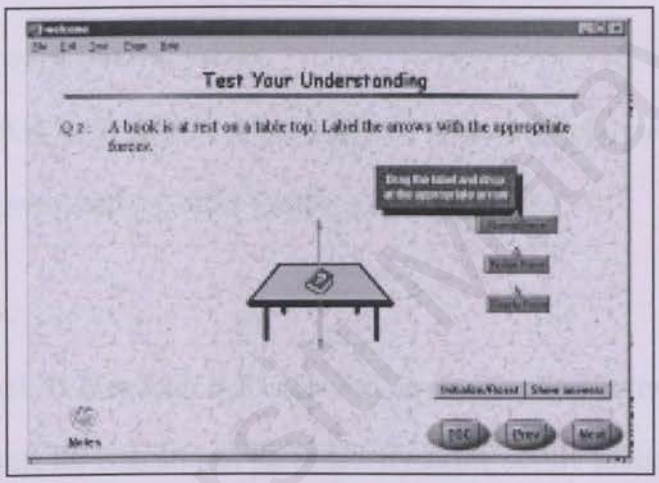
Figure 4.14: Feedback Example 1



Users will know whether their answers are corrected or otherwise. If the given answer is incorrect, they are encouraged to try again.

Another type of feedback is to inform users about the function of the icon whenever they point their mouse on it. Figure 4.15 shows the example. This feedback helps users to recognize the icons without memorizing their functions.

Figure 4.15: Feedback Example 2



Chapter 5

Implementation and Evaluation

The design and methodology described in previous chapter are used to realize the project objective. Some scripts of working screens are included to visualize the system implementation. System testing and evaluation complete the research process.

5.1 Tools for Software Development

For the implementation of FORPHY, two different types of tools are used, one for the main system development and the other for the graphics.

Major Tool

Asymmetric ToolBook II Instructor 7.1 is chosen as construction software because it has several features suitable for educational purposes. It has the ability to represent information graphically which is much more effective than using text. Drawings, scanned images, color, animation and sound can enhance the proposed tool. It supports all the features of Windows applications such as graphical user interface, event-driven programming, and the ability to interact with other Windows applications. It is suitable for creating an interactive application, which requires graphics, buttons, fields, and so forth. OpenScript is its programming or scripting language used to define the action at certain events such as click button, enter page etc. Its tutorials, learning center and examples of application developed provide excellent guides the first time novice users.

It also provides variety activity in catalog form, which allows users to choose the preferred ways to test their students. Users can simply pick the catalog and bring to the book for editing the contents. It saves a lot of time in preparing scripts and gives a lot of idea to users to create different approaches to test.

Additional Tool

Adobe PhotoShop 5.0 is used to edit several BMP, GIF and JPG graphic to be embedded in the tool. Those graphics may be copied from the internet or created from scratch. Graphics are for not only the object needed but also its background. Background images may be edited to make them transparent. Although Asymmetric ToolBook II Instructor 7.1 supports the feature, not all graphics are applicable.

5.2 Hardware Requirements

The proposed cognitive tool is implemented on a stand-alone personal computer, on the Microsoft Window 98 platform. It runs well enough on Pentium® II processor with the Intel MMX™ technology. It also requires at least 4MB RAM (8MB recommended in User Manual, 6MB recommended on packaging).

5.3 System Description

Below are the specific descriptions of the prototype.

Brief Notes

Brief notes are provided in the earlier lesson with the objective to establish the fundamental concepts before students can start using the tool. It provides knowledge on the topic through the simple notes and animations.

Exercises

FORPHY guides users to develop the correct mental model about forces. To stimulate the users' interest, different interactions are required from the users. The test is vital because it indicates how well the learners understood the topics. They can evaluate their level of understanding and can plan remedial or improvement activities. Learners can do the test after reading the notes or access it directly. For the earlier part of the test, answers are given by the system. Users are then allowed to try to answer on their own. Students are to think about the most reasonable answers. Therefore students should be able to figure out whether the answer is an acceptable answer.

Learning Activities

Two learning activities provided are as below

- Drag and Drop

  The drag and drop approach allows learners to match the arrows drawn in the diagram with the appropriate label of force. They need to drag the label and drop at the arrow. Once the arrow is labeled, the tool prompts a short message that indicates whether the users has labeled correctly. The prompted messages are useful to inform the users about the status of answers given. If they want to repeat the exercise or cancel the action, they may click on the initialize button. Drag and drop label develops the learners' skill in identifying the type of forces acting on the object and the force direction. This is the first and foremost skill that they need to practice in learning force.

- Draw free-body-diagram

  Draw free-body-diagram approach allows the students to draw the diagram freely. It is important for students to have skills in drawing the free-body-diagram, including identify types of forces act on the object and the force direction. A free-body-diagram shows only the object in the question and the forces acting on the object. Forces are represented as arrows. Students who are good in sketching the appropriate diagram will have no problem to find solutions. To enhance learners understanding about the concept of forces, they are allowed for several trials to correct their mistakes, i.e. they are allowed to redraw the diagram again and again until they get the correct one. The diagram drawn by the students must relate to the question given. If the arrow is in an opposition direction, or labeled with the inappropriate type of force, short messages will be prompted. The messages show the status of the answer and encourage users to keep on trying until they find the correct answer. The students are given two choices either to repeat the exercises or otherwise.

5.4 System Implementation

The main objective of this system implementation is to produce a fully functional application so that it is user friendly. Two main processes that have been carried out in the system development are described below.

a) Constructing the framework

The program is mainly developed using ToolBook Instructor II 7.1. The framework of FORPHY comprises:

- Preparing content of notes

  The first task that has been done is building the notes material. The precise definitions for all forces are typed in the text editor. A page of notes has one or two defined forces and space left is for animation.

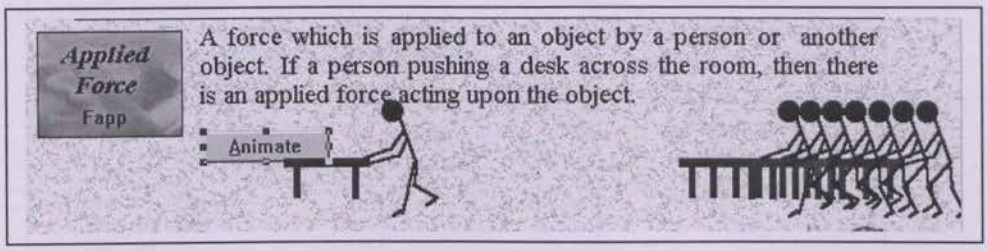
- Preparing exercises

  This section has a set of questions to test users' understanding. The questions used apply a variety approaches such as drag and drop, draw the force arrow and make selection.

- Creating animations

  Different animations are used for different type of forces. A suitable animation is developed to ensure that it meets the purpose and definition for each force. To animate the still images, several layers of the same images are copied and pasted on various locations. Some layers required a little change in order to make the motion images look real. Figure 5.1 illustrates several copies of a person pushing a desk across. Once the animation is done, all of the layers are hidden except the final layer. Other alternative to create animation is using a feature provided by ToolBook. It records animation by moving the still image and can be edited as well.

Figure 5.1: Creating Animation



- Preparing feedbacks

  A few feedbacks are designed at certain users' interaction. The purpose of the feedback is to let the users know whether their action is correct or wrong. Not all users' action is provided by feedbacks. This is to encourage users to think the rationality of their action taken. Figure 4.14 shows the feedback.

b) Adding navigation

Buttons, menus and links are navigational methods used in the FORPHY. There are designed to ease the users to navigate from a page or a link to another.

5.5 Sample Scripts and Explanations

Figure 5.2, shows a script for a button *Animate* shown in Figure 5.1. The person image is set at a specific coordinate on the page. There are 24 layers of the person images, it is hid and shown in sequence order. When the last layer appeared, the arrow that represents the direction of affected force blinks four times. This is to notify the learners. The bottom part of the figure shows whenever the mouse pointer is pointed to the button, its shape will be changed to hand pointer.

Figure 5.2: Sample Script 1 - Animation

```
to handle buttonClick
        set sysCursor to 4
--      set position of group id 60 to 8000,1600
        hide group "g24"
        show group "g1"
        pause 10 ticks
  step i from 1 to 23
    show group("g"&i+1)
    hide group("g"&i)
    pause 25 ticks
    end step
    pause 25 ticks
    show group "g24"

--show group "g1"
--show group "g2"
--show group "g3"
--show group "g4"
--show group "g5"
--show group "g6"
--show group "g7"

hide line"arrow1"
        step y from 1 to 4
                pause 40 ticks
                show line"arrow1"
                pause 80 ticks
                hide line"arrow1"
                end step

set sysCursor to 1
end buttonClick

to handle mouseEnter
set sysCursor to 44
end

to handle mouseLeave
set sysCursor to 1
end
```

To animate a walking man

To blink the arrow

To set the shape of pointer

Figure 5.3 shows a part of the script to drag and drop function. The function is used when the users need to label the forces. It is provided by the ToolBook and is customized to meet the need.

Figure 5.3: Sample Script 2 – Drag & Drop

```
notifyAfter ASYM_SummonWidgets
        send ASYM_IAmWidget to self
end

------------------------------

notifyAfter objectDropped obj, loc
        send ASYM_CheckDropObj obj, loc to self
end

notifyAfter ASYM_ObjectDropped obj, loc
        send ASYM_CheckDropObj obj, loc to self
end

notifyAfter ASYM_BeginDrag obj
        if obj is in my responsel ist
```

5.6 System Testing and Evaluation

Upon full completion of FORPHY, the following action to be taken is testing. Beta testing is conducted externally by the users of the system. The testing focuses on users' reaction on learning outcome. The objective of the questionnaire prepared is to check whether FORPHY meets its objectives. The first part of the test assesses the system content and the last part assesses the overall system.

Questionnaires were distributed among the secondary school students nearby after they tried FORPHY for several times. Table 5.1 and 5.2 summarize the users' responses.

Table 5.1: The Test Summaries – Part 1

	Analysis Result				
	Strongly disagree	disagree	unsure	agree	Strongly agree
1. Do the animations provided are adequate?		38%		62%	
2. Do the animations make sense to you?		10%	10%	80%	
3. Do FORPHY provide enough description of forces?		45%		55%	
4. Do FORPHY provide enough exercises?		56%		44%	
5. Rate the level of difficulties of the exercises given.		30%	15%	55%	

Table 5.2: The Test Summaries – Part 2

6. Have you ever visited the computer based instruction in learning any subject?	23%	50%		27%	
7. Are there any skills develop upon system completion?		12%	14%	74%	
8. Is the concept emphasized conflicting with yours?		95%		5%	
9. Do you have confidence in identifying types of forces?		22%	18%	60%	
10. Are you being able to visualize the motion of object with forces acting on after experimenting FORPHY?		23%	15%	55%	7%
11. Is there any new knowledge obtain after executing the system?		15%		34%	22%
12. Overall, how satisfied were you with the FORPHY approach in helping you to understand the force concept?		17%	3%	12%	68%

The Part 1 Test shows that users are mostly satisfy with the number of animations and explanation of the content. Some would prefer to have detail elaboration of the topic. They were very enthusiastic to have more exercises to practice and the exercises given are not too difficult for them. In conclusion, detail explanations and variety of animation examples stimulate learning interests which lead them to know and explore the topic further.

Part 2 Test shows that although respondents get less exposure on the computer based instruction they still have potential to learn the topic delivered in the new form. They have improved their ability to identify the forces and visualize the motion object. The higher satisfaction achieved shows they are happy with the application because it really helps them in their study. They did learn from the tool tested. In brief, FORPHY could help them to develop concrete understanding of the forces concept.

5.7 System Strengths

Several strengths of the prototype have been identified. There are:

Repetitive Attempt

Students may repeat testing the question as many as they want. No restriction for the numbers of attempt. They are freely to try the questions without having to find the correct answer before proceeding to the next page.

Easier navigation

FORPHY applies very simple system navigation. It uses compound navigation where at the beginning the students may choose any topic to go through. Once they click on the option, for example the test pages, students are only able to navigate

the pages in a sequence order. Students have high accessibility to the topics they prefer most.

Animation

All examples provided are in the form of animation. Using animation helps to attract students' attention and therefore increases students' interest to learn the topic further. Animation is used to show the effects of each action taken, which guides students' thinking ability.

No Assessment

There is no assessment method provided in the proposed system. The idea is not to evaluate students' achievement but it is actually to promote students learning ability and interest in forces. For a few questions, feedbacks are given on the correct attempts. The reason is to develop student's confidence which will persuade them to try the following questions. The last part of the questions provides no correct answers.

Feedback

Short feedback is designed to acknowledge students either their answer is correct or wrong. The feedback is only available for a few early questions. The reason is to make students feel comfortable hence lead them to try further.

Cognitive Improvement

The animations developed demonstrate the motion of the object base on the certain attributes. As students go through the questions, their cognitive level is change and

improves. Their new constructed knowledge is the most valuable outcome from the system.

5.8 System Constraints

The development of this cognitive tool has several limitations.

Help Module

It is not supported with the help module. Users will face problems if they require further explanation of the functions provided. Help module should be as a complementary module in the tool, so that the users can access it at anytime.

Magnitude of Force

This cognitive tool should be able to teach users in representing the force with its magnitude. Without magnitude, students cannot differentiate which arrow of force carries a bigger force. Different size of magnitude states different magnitude of force.

Reference Sources

The reference books in writing script are quite difficult to search in the library or internet. Most of the information obtained is located from the mailing list group from outside of the country.

Chapter 6

Conclusion

The majority of the objectives of FORPHY have been achieved, although there are some areas where the amount of work needed was underestimated during the design stage. The testing result shows the students understanding about forces can be enhanced. It is proven when their skills in identifying forces and visualizing the motion object are successful and thus lead them to solve the problems given.

Some difficulties in learning forces are solved through drawing activities. They are confident to draw and label the forces because they have obtained a good understanding of the concept of force. This improves students' problem solving skill.

The analysis also shows the importance of having animations for every topic discussed. The animations portray the real situation which these could not be done in the classroom. More animations stimulate more learning interest and therefore reduce misconceptions about forces.

6.1 Future Enhancement

FORPHY is designed as an interactive tool in order to provide better learning environment to students. It can be used as an additional module which helps students to develop concrete mental model of the topic. With the current multimedia technology it can be developed as a versatile application tool. The addition of sound and movie clip, will make

the animation more realistic. It should benefits students in enhancing their knowledge of force.

Animation is identified as a key factor to increase students' motivation and enhance their quality of learning. The strong visual presence can also increase the students' enjoyment of their learning experiences. Animations in FORPHY do not really move smoothly like a video. It is affected by the number of frames or layers created. However, to increase the number of frames will cause a delay because it requires a lot of storage. To ensure the smoothness of the animation and lessen storage needed, it is better to use the recording feature provided by the software.

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APPENDIX

QUESTIONNAIRE

The purpose of this experiment is to evaluate the effectiveness of FORPHY to help students in establishing their knowledge of the concept of forces.

You are required to shade only one indicator as shown below.

①	②	③	④	⑤
Strongly disagree	disagree	unsure	agree	Strongly agree

SECTION A

This part of questionnaire assesses the content of the system.

1. Do the animations provided are adequate?	①	②	③	④	⑤
2. Do the animations make sense to you?	①	②	③	④	⑤
3. Do FORPHY provide enough description of forces?	①	②	③	④	⑤
4. Do FORPHY provide enough exercises?	①	②	③	④	⑤
5. Rate the level of difficulties of the exercises given.	①	②	③	④	⑤

SECTION B

This part of questionnaire assesses the entire system.

6. Have you ever visited the computer based instruction in learning any subject?	①	②	③	④	⑤
7. Are there any skills develop upon system completion?	①	②	③	④	⑤
8. Is the concept emphasized conflicting with yours?	①	②	③	④	⑤
9. Do you have confidence in identifying types of forces?	①	②	③	④	⑤
10. Are you being able to visualize the motion of object with forces acting on after experimenting FORPHY?	①	②	③	④	⑤
11. Is there any new knowledge obtain after executing the system?	①	②	③	④	⑤
12. Overall, how satisfied were you with the FORPHY approach in helping you to understand the force concept?	①	②	③	④	⑤

Thank you for your participation in this experiment.

User Manual

A. Software Profile

Forphy is a application tool which is specifically developed to introduce forces in physics for a new learner. It helps student to build a fundamental concepts of forces at secondary school.

Forphy has two sections:

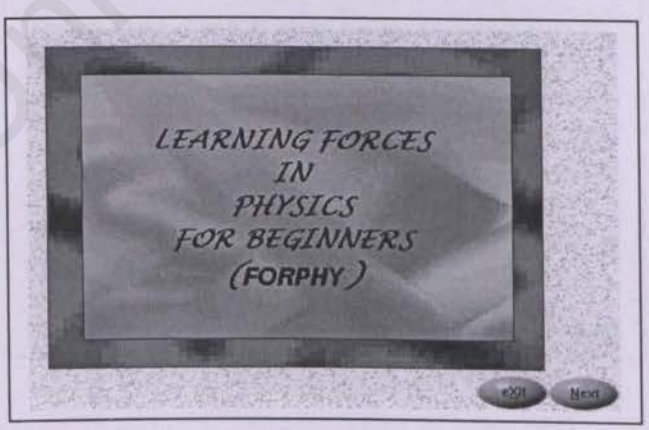
- **Lessons and Examples Section**
  In this section, brief descriptions and simple examples of each forces are introduced. Students may test the examples as it will guide them to understand the concept better.

- **Students' Activities Section**
  This section presents several forces problems and requires students to find solutions. It is designed purposely to develop students' problem solving skills and to enhance their interest in learning physics. The section allows students to try several times until it meets students' satisfaction.

B. Getting Started

- **Welcome page**
  Once student executes the application, the welcome page will be displayed. If the student wants to proceed, click on the "Next" button or else click "eXit" button to close the application.

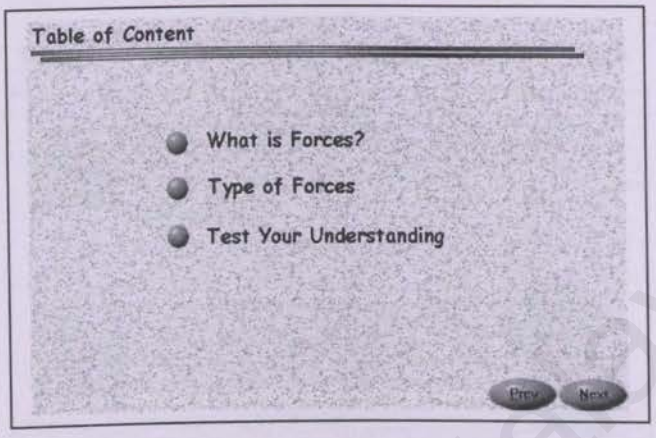
Figure 1: Welcome Page



➢ **Table of Content page**

This screen provides three options for student to choose. See Figure 2. The first option will link to the Definition page. The second option will link to Type of Forces page. The last option is linked to pages where students understanding will be tested.

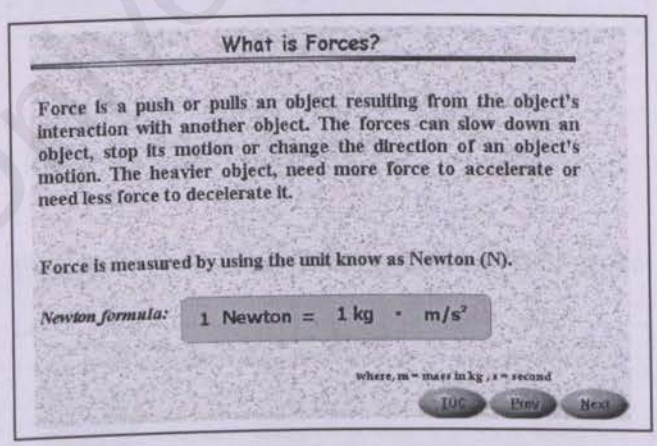
Figure 2 : Table of Content



➢ **Definition page**

The pages consist of a complete definition of force, a formula and animated example. See Figure 3.

Figure 3: Definition Page



➢ **Type of Forces page**

In this part of note, all types of forces are defined and each of them is given an animated example. Figure 4 provides information for Applied Force and Gravity Force. Click the "Animate" button to run the animation. For example if the "Animate" button for the Applied Force is clicked, students will see a man is pushing a table across the room. See Figure 5.

Figure 4: Note for Applied and Gravity Forces

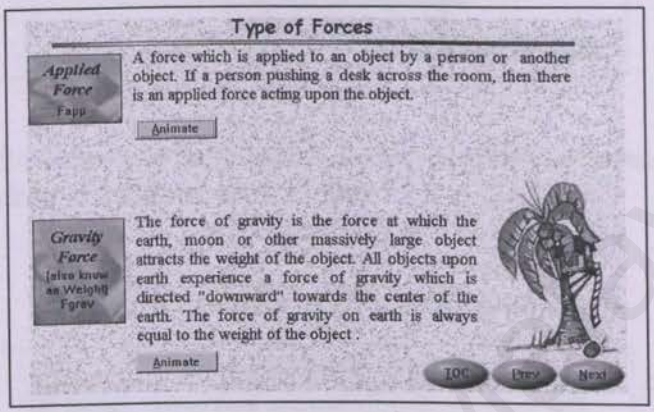


Figure 5: Animation for Applied Force

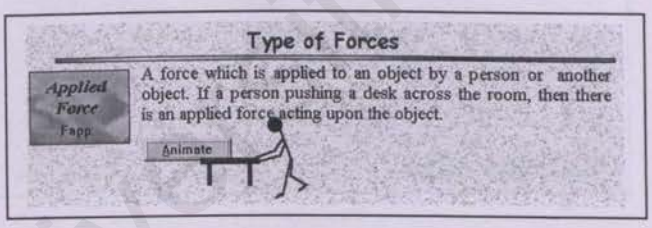
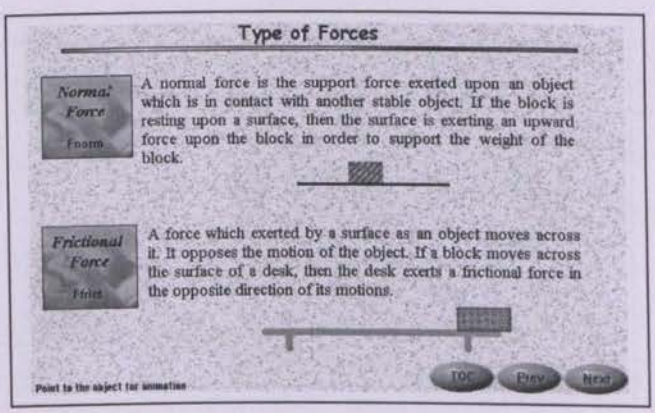


Figure 6 shows the following page of forces.

Figure 6 : Note for Normal and Fictional Forces



To see the animation for this page, student is required to move the pointer over the box.

Figure 7: Animation for Fictional Force

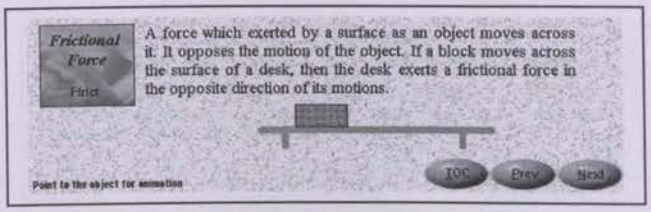


Figure 8 is the following note page which is Air Resistance Force. To animate, the action should be taken is the same as in Figure 7.

Figure 8: Note for Air Resistance Forces

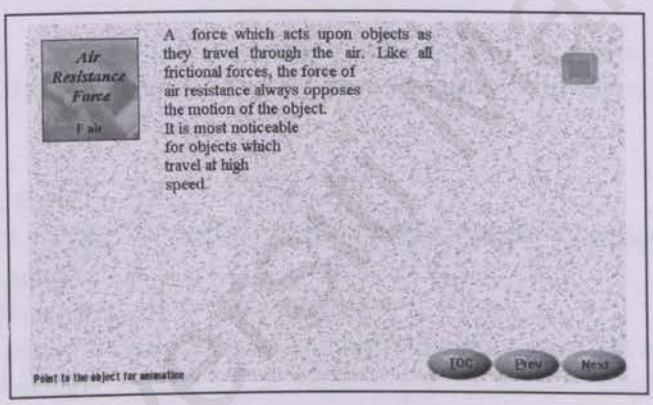
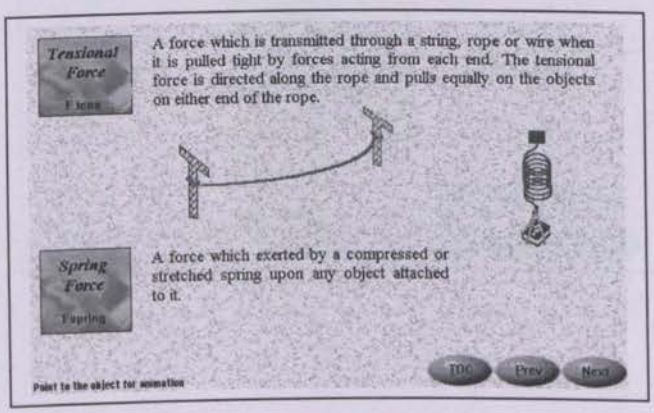


Figure 9 is the note page for Tensional and Spring Force. To animate, the action should be taken is the same as in Figure 7.

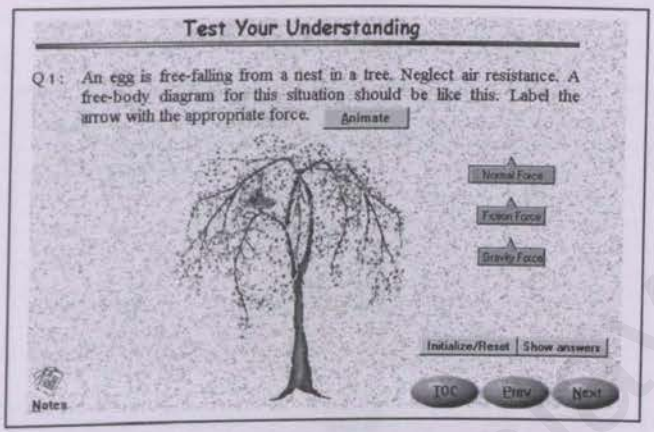
Figure 9: Note for Tensional and Spring Force.



➢ **Test Your Understanding page**

At this section, a set of six simple forces problems are presented. These pages apply several learning activities. Students may attempt the question as many as they wish to. See Figure 10.

Figure 10: Sample of Question



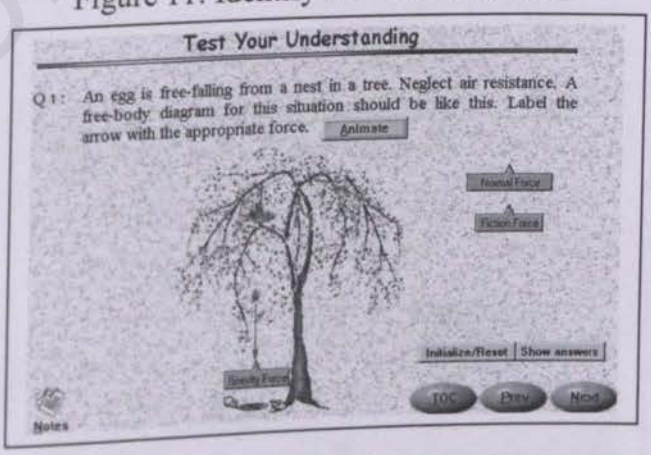
After reading the given problem, students will be able to view the animation that visualizes the actual problem. Then student should recognize kind of forces involves.

How to label the force?

1] Click on the "Animate" button to allow the application to appear the arrow which represents forces act on.
2] Drag the tags provided and drop to the arrow.
3] Click the "Initialize" button to undo the latter action or to start all over again
4] Click "Show Answer" button if you want to get the answer straight away.

The tag is valid only for the right attempt as shown on Figure 11.

Figure 11: Identify and Label the force



How to draw the force line?

1] Point your mouse near to an object

2] Click the mouse to draw a line. The red arrow will appear upon drawing.

Label the identified forces. See examples shown in Figure 12, 13a and 13b.

Figure 12: Draw and Label Arrow

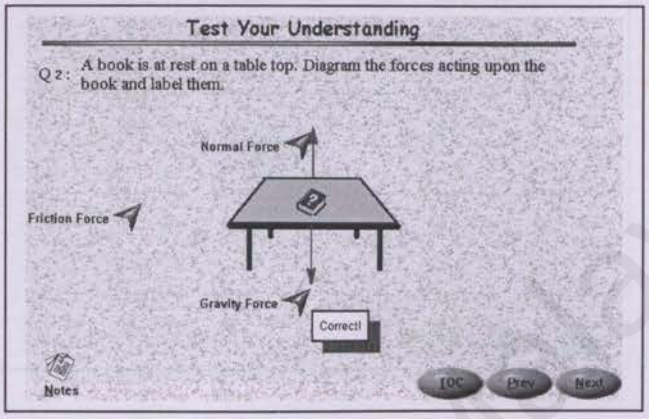


Figure 13a: Draw Arrow

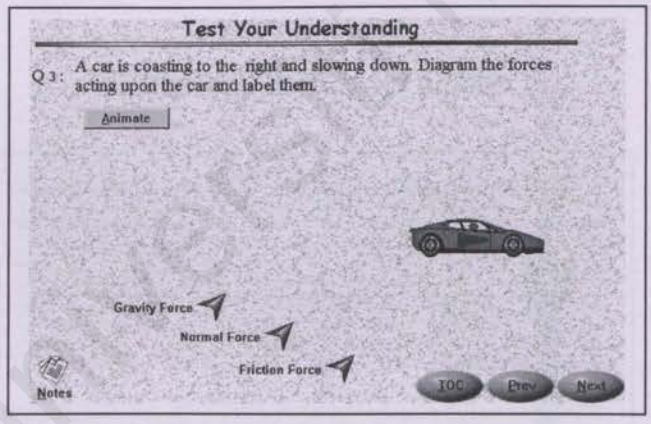
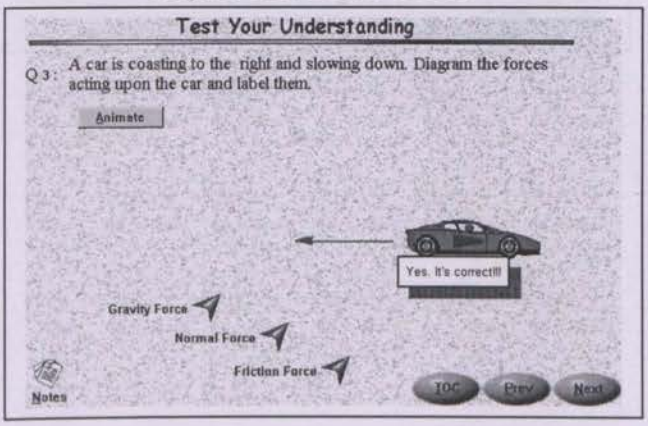


Figure 13b: Draw Arrow



The following problem pages allow students to choose selection of different Newton values. For each selection, the object will move accordingly. See Figure 14a and 14b. To close the application, students may click on "eXit" button.

Figure 14a: Selected Option

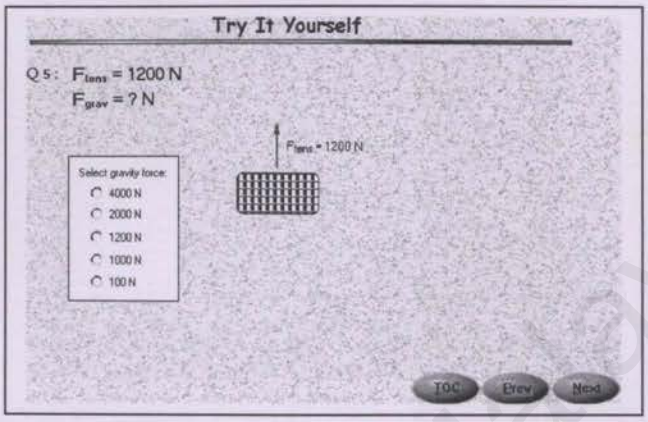


Figure 14b: Selected Option