Choosing the predict option

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Abstract

An interactive multimedia module that introduces first year university physics students to basic concepts and relationships in rotational kinematics is described. Students using this module have shown a significant improvement in their understanding of the fundamental angular concepts. They have also demonstrated a preference for spending time on prediction type activities.

Keywords

Rotation, kinematics, motion, physics, simulation, interactive, multimedia, concept.

Introduction

Rotational kinematics is generally introduced to physics students in their first year at university. Although rotating objects are in our common experience, the quantities used to describe this motion are not. Even so, rotational kinematics is often covered rather quickly because of a strong analogous relationship with the more familiar rectilinear kinematics. The use of analogy is common in the introductory chapter on rotational motion in first year university physics textbooks. Indeed a cursory inspection of the first table in this chapter for two of the most popular textbooks (Halliday, Resnick, & Walker, 1997, p.243; Serway, 1996, p243) show rotational equations and their analogous linear equations side by side.

Unfortunately, many students have not sufficiently mastered the concepts of velocity (Trowbridge and McDermott, 1980) and acceleration (Trowbridge and McDermott, 1981) to apply in a real situation, and for these students the use of analogy in teaching rotational kinematics is not likely to succeed. Students' misconceptions and difficulties encountered in learning kinematics abound the research literature and an excellent bibliography can be found in Arons (1996).

An interactive multimedia approach provided a unique opportunity for students to gain concrete experiences with rotational variables through the use of simulations rather than more abstract experiences through analogy. Financial support of $20,000 was granted by ECU (Edith Cowan University) to develop an interactive multimedia module in rotational kinematics. The module was developed over two years and first introduced to students in semester 1, 1998.

The rotational motion module

Macromedia Director was used to create this module which can run on both PC and Mac platforms. Central to the module is an interactive simulation of the rotating blades of a wind generator through which angular concepts are explored. For smooth and realistic simulations, a high-speed Pentium PC (or equivalent Mac) with a large amount of RAM (about 40MBytes) is required. The 360 wind generator images, one for each degree, require 27.8MBytes of RAM alone.

The module's content is divided into the following five topics:

- angular position and displacement
- angular velocity
- angular acceleration
- linear variables (and their relationship to rotational variables)
- rotational (kinematic) equations

Within each topic, students can access up to three distinct types of pages. *Play* pages provide opportunities for students to get a "physical feel" for the rotational quantities. Diagrams and/or simulations support the topic content on *theory* pages. Students can apply and test their knowledge on the *predict* pages. Screen dumps from the module are shown in Figures 1, 2, 3 & 4 which illustrate the three different types of pages and give an overall feel for the interactive multimedia experience.

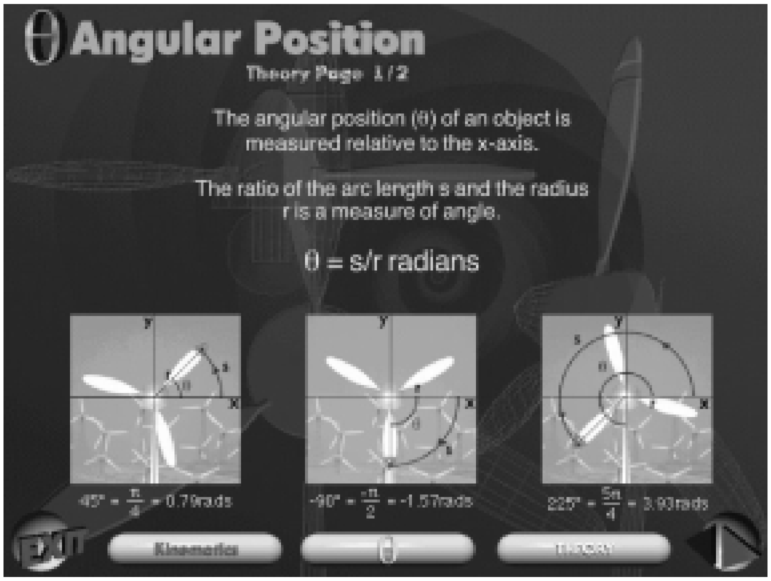


Figure 1: Angular position: Theory page 1. The angular position quantity is defined and examples for the (red) tipped blade of the wind generator are given.

Theory pages (see Figure 1) provide the topic content through text, equations, examples, diagrams and/or simulations. They tend to have a larger amount of text than other pages with most topics having two theory pages: the first page providing a more visual experience with the concept, and the second page having a more mathematical approach. Appropriate simulations support both angular velocity and angular acceleration theory pages.

Play pages contain interactive simulations that are designed to help students get a "physical feel" for the relevant quantities. Figure 2 shows the play page for angular velocity. The angular velocity of the rotating blades is varied in real time by dragging (using the computer mouse) the sliding bar. A similar page exists for angular acceleration where the student varies the angular acceleration and sees both the values of angular acceleration and angular velocity in real time.

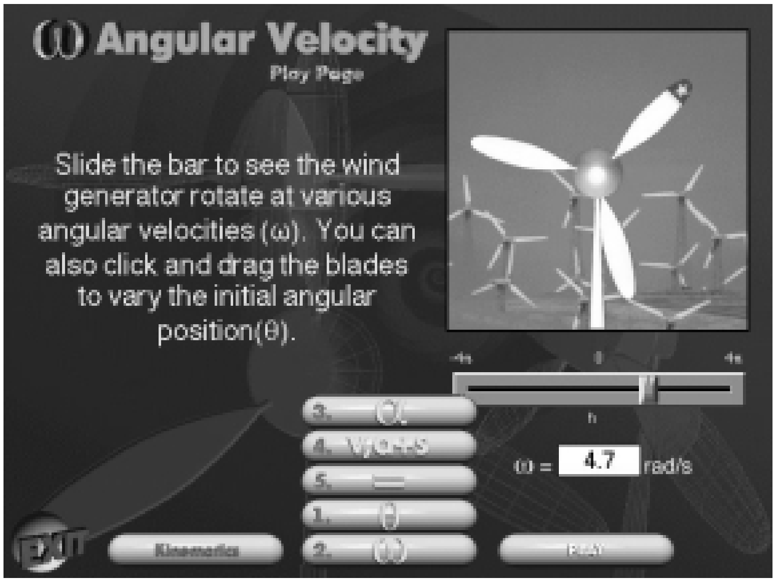


Figure 2: Angular velocity: Play page with topic icon activated

The topic navigational icon at the bottom of the screen in Figure 2 has been activated. Although students are free to progress through the topics in any order, the numbering provides a subtle indication of a logical sequence.

Predict pages give students an opportunity to apply their knowledge to solve quantitative problems. In Figure 3, the user has selected two of the three known variables and has then calculated and entered the values for the two unknowns. Unfortunately, one of these values is incorrect and a hint (in the form of the correct equation) has been given. There is thus a second (and final) chance in which the correct answer is either inserted by the student or by the computer program.

Once the correct answer is on the screen, a simulation of the corresponding motion occurs. In this particular numerical example (Figure 3), the simulation will show the rotating blades slow down in one direction and then speed up in the opposite direction. The author has observed that many students have an incorrect "speed up" or "slow down" only conception for a given acceleration. This particular simulation should challenge that conception.

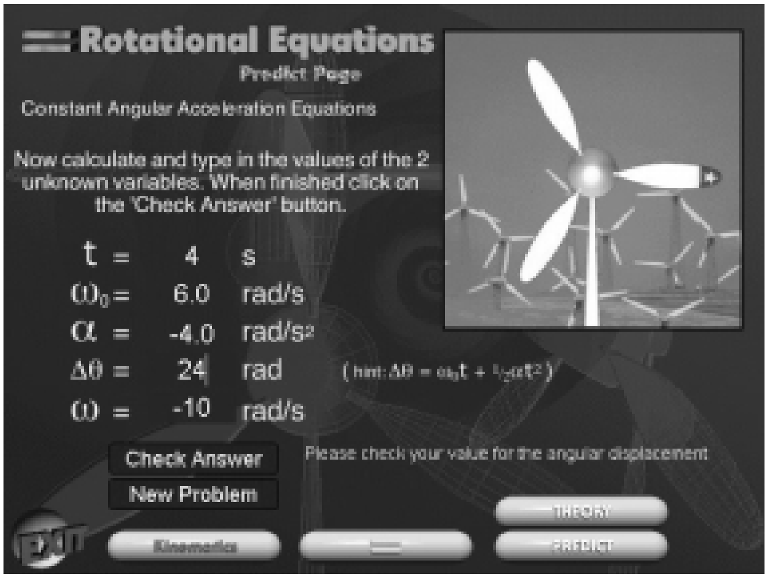


Figure 3: Rotational (kinematic) equations: Predict page with page type icon activated

The page type navigational icon at the bottom right of the screen in Figure 3 has been activated and shows the two page types available for rotational equations.

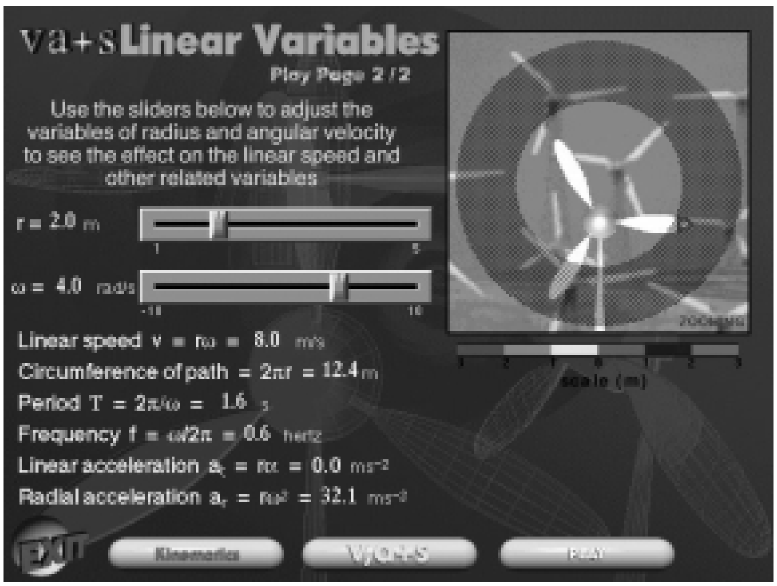


Figure 4: Linear variables: Play page in zooming mode

The linear variables play page (Figure 4) aims to show students the linkage between rotational quantities and the more familiar linear quantities. The angular velocity and radius are varied by dragging the corresponding sliding bars. A zooming function illustrates the changing scale of the wind generator when the radius is changed. The corresponding values for a wide range of related variables are displayed as the rotating blades demonstrate the motion. The aim is to reinforce all of these concepts through their interdependence.

The zooming function also represents a compromise so that students can see the affect on linear variables when the radius of rotation is changed without having to wait for 360 new images of the wind generator to be loaded into RAM for each radius. It works by changing the size of the single background image with the illusion (given by the telephoto lens and expanding scale) that the size of the wind generator is changing. Unfortunately, the telephoto lens analogy is not strictly accurate as objects seen through a telephoto lens only appear bigger.

The common navigational icons situated at the bottom of the screen (Figures 1–4) allow students to easily move between the different topics and types of pages. Although there is a suggested sequence in which to study the topics (see Figure 2), there is no suggested sequence for the different types of pages within each topic. An open architecture gives complete flexibility to the students in how they are going to sequence the 17 pages of content.

Case study subjects and design

Students enrolled in the SCP1111 Physics of Motion unit at ECU took part in the trial in semester 1, 1998. A test designed to measure conceptual understanding was given to all students one week after covering rotational kinematics in (a traditional) lecture. Students who demonstrated conceptual difficulties in the lecture test were given the opportunity to take part in a trial with the multimedia module. Fifteen of these students (plus two other students) took advantage of this offer in the following week.

The trials took place in an ECU multimedia research laboratory equipped with four Power Macintosh computers linked to videotape recorders. Each trial took about sixty minutes to complete and four sessions were necessary to cater for the eighteen students.

Each group was given forty minutes to interact with the module. Six students chose to work individually (group of one), eight students worked in groups of two, and three students worked together in a group of three. They were given no guidance on how they should use the module. The computer screen and conversations were recorded for each group on videotape.

Each student completed an identical pre- and post-test to measure the affect of the multimedia experience on their conceptual understanding. These tests differed from the lecture test only in context and the actual numerical answer. The tests contained 10 questions: 3 on angular position and displacement, 3 on angular velocity, and 4 on angular acceleration. They were given 10 minutes for each test.

Students were also asked to evaluate the module as well as their own experiences and learning outcomes.

Results & analysis

In evaluating the module, students agreed that the information was clearly presented on the screen and that the module was easy to navigate. They believed that their understanding of the content had improved and that predict type pages helped them the most. These perceptions are in good agreement with test and videotape data.

Test results

Figure 5 shows the average percentage of correct answers in each of the three conceptual areas and overall (total) for the lecture-, pre-, and post-tests. The pre- and post-test results show that students on average have improved their overall score after interacting with the interactive multimedia module. An improvement also occurred in each of the three conceptual areas: angular position and displacement, angular velocity, and angular acceleration.

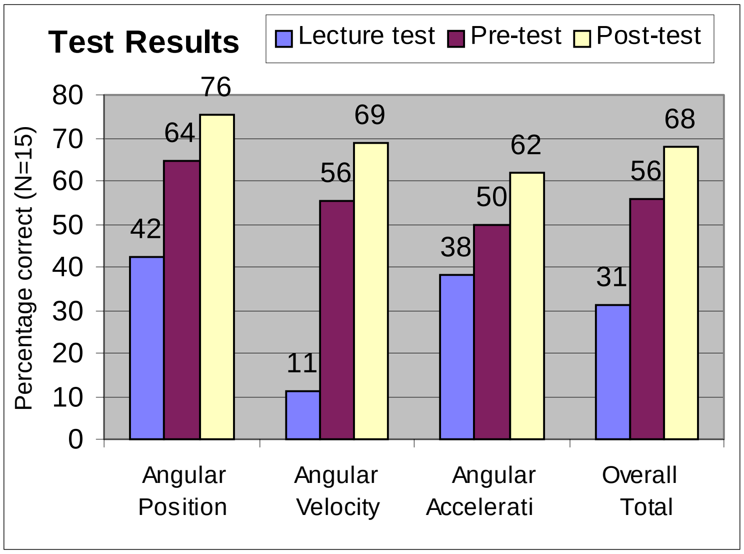


Figure 5: Test Results showing improvement (N=15 students)

The improvement in overall scores from the pre- to the post-test is small but significant. Nine students improved their overall score and six students stayed the same. A Wilcoxon signed ranks one tailed test (Burns, 1997, p. 177-181) on this data (N=9 & T=0 giving $p<0.005$) demonstrates the improvement is significant with a high level of confidence.

The author does however acknowledge that significant improvement would also be likely given forty minutes in various other more traditional learning situations. In fact, there is a greater overall improvement between the lecture test and pre-test (see Figure 5). This improvement is also significant (Wilcoxon: N=11 & T=0 giving $p<0.005$) indicating that students had probably spent time studying the material in between these two tests. In particular their understanding of angular velocity, a core concept in the IMM module, showed a large increase.

Videotape results

Although groups were allowed up to 40 minutes to interact with the module, some groups exited the module earlier. The average time spent per group was 34.4

minutes[1]. In this time, most groups accessed each of the 17 possible pages at least once.

Each group was observed to use the package in a unique way. For example, some students took extensive notes of theory pages before moving on. Other students focused on the play pages, or spent almost all their time on the predict pages. Conversation was minimal and certainly less than expected by the author.

The percentage of time spent on each of the five topics is shown in Figure 6. Students spent the least amount of time on the three topics dealing with the core fundamental quantities of angular position, angular velocity and angular acceleration. They chose to spend most of their time on the rotational equations topic.

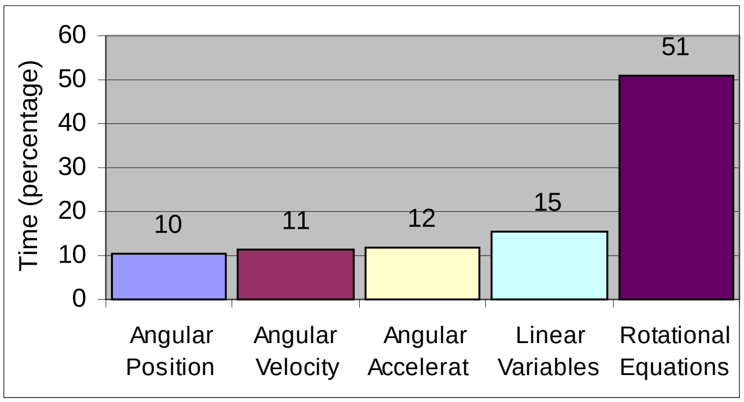


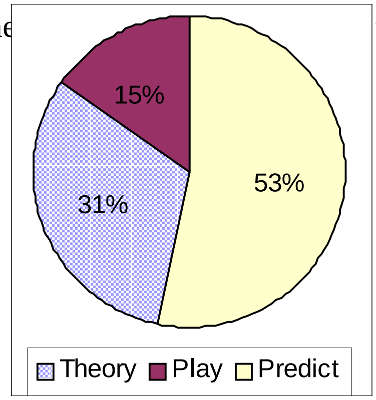
Figure 7: Percentage of time spent by groups on the three types of pages

The percentage of time spent on the three different types of pages is shown in Figure 7. Students spent most of their time on predict type pages and only a small amount of time on the play type pages.

A staggering 43% of the overall time was spent on just one page; the rotational equations predict page.

[1] Not including the 1.6 minutes spent on the introductory sequence. Students cannot return to this sequence once the first topic page has been chosen.

Figure 6: Percentage of time ... the five



Discussion and conclusions

Why would groups choose to spend almost half their time on just one page; the rotational equations predict page? Probable reasons for this choice include a familiarity in learning physics through applying formulae in repetitive exercises, and experience in what sort of activities have been useful in passing previous physics exams. The rotational equations predict page provides drill like exercises, and as such is both one of the most mathematical and least conceptual pages in the module.

In contrast, the play pages are the least mathematical and most conceptual pages in the module. Indeed the play pages were central to the conceptual development aims of the module and were also the major reason for developing an interactive multimedia approach for these topics. However, this sort of activity is least familiar to students in learning physics and students overall chose to spend the least amount of time here.

Student usage of this module is somewhat contrary to the original rational for developing the module: to develop concrete conceptions of rotational quantities. This has implications for the design of multimedia modules and the environments in which they are used. Students' prior learning and study habits need to be taken into account when designing interactive multimedia modules as well as their goals and aspirations.

Most students in this physics unit are not physics majors and tend to be motivated more to pass than any intrinsic interest in the content. They therefore use familiar and successful modes of study to learn the material. A higher level of interactivity in the design of the less familiar play pages may have encouraged students to spend more time here and this is being considered for a future version of the module.

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