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Hands-On Activity for Conceptual Understanding of Rigid Body Kinematics

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Work in Progress: Hands-On Activity for Conceptual Understanding of Rigid Body Kinematics

Introduction

Rigid body kinematics is the study of the motion of non-deforming objects. In a traditional American university or college, students are taught this subject of dynamics primarily through one-sided lectures, with a large emphasis on descriptive mathematics [1]. Feedback from panels, blue-ribbon commissions, and the Accreditation Board for Engineering and Technology suggests that these methods of instruction lack efficacy in engineering education [3]. Studies have shown that students study harder and develop greater skills with the material when they are interested in the subject matter and believe there is a reason to understand the concepts [3]. Cognitive studies have also shown that people often learn new material contextually, by attaching it to previous experiences and existing knowledge [3]. Rigid body kinematics is an excellent subject to draw upon prior knowledge and experiences, as many of these systems are prevalent in the real world.

Alternative approaches applied by other researchers teaching the subject have involved the separation of rigid body motion from the mathematics. In their approach, students observed practical applications of rigid body kinematics through videos, pictures, and the actual operation of some machinery [1]. The goal of this approach was to provide students with the opportunity to develop motivations for studying the subject and to later recognize the mechanisms of system operations. Other approaches used interactive simulations with variable parameters for students to alter and observe their direct effect on the motion of the system [1]. The specific simulations included four-bar linkages, two-link robots, and rotating disks. Test scores from the institution implementing this technique were encouraging and suggest that this approach may be suitable for students who seek careers in design and manufacturing fields [1].

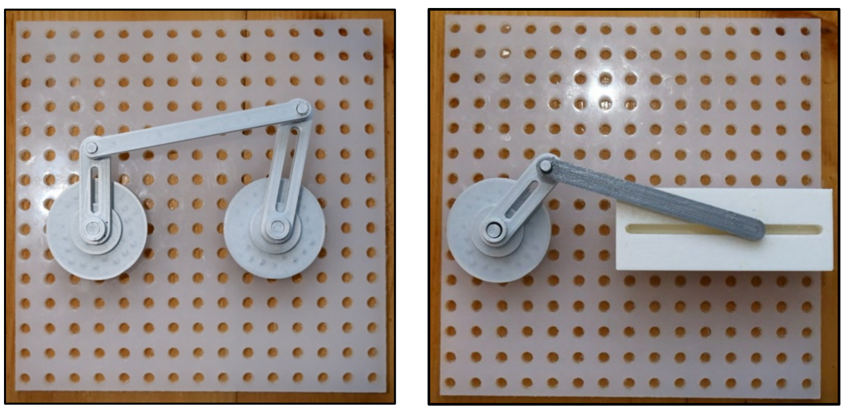
In a dynamics of machinery course, rigid body kinematics was taught with the goal that students would develop a curiosity for real-world applications of the mechanisms taught in the course [2]. This group assigned students to find real-life examples of the mechanisms covered in class and to take photos or videos of them to later describe the motion of the mechanisms (through calculations and diagrams). Students were also assigned a design project with an open-ended and unstructured problem to solve. Students were surveyed and asked for feedback on the course project. Their results revealed that only 28% of students found the project to be helpful as a teaching method [2]. Student feedback mostly indicated that the project was time-consuming, taking away time from studying for exams. However, a majority of the student feedback regarding the exploration of real-life examples showed that they found it useful to gain interest and motivation for studying the course material [2]. Their results suggest that a careful balance of open-ended real-world application and standard course material should be optimized for student learning and performance.

Our team is exploring new alternatives in delivering rigid body kinematics course content. The essence of our approach involves a cycle of prediction, observation, and explanation through hands-on activities covering various dynamic scenarios. One of the goals of this approach is to draw upon the intuition that students may have regarding the motion of rigid bodies. After students predict how a scenario may play out, they immediately observe that scenario to provide immediate real-world feedback. This can either reinforce the student's confidence in their intuition or reshape how they visualize such situations. Following the observation, students are tasked with explaining the events using dynamics principles. Students are encouraged to apply concepts from relative motion - including position, velocity, and acceleration, to connect their observations to the principles taught in dynamics. We also believe incorporating kinesthetic learning allows students to gain a new perspective in how they visualize and conceptualize rigid body kinematics scenarios.

Implementation

The first stage of development of our rigid body kinematics activity involved drafting conceptual problem sets that challenge students to think about various scenarios without an analytical approach. These problem sets are assigned prior to the hands-on activities to give students a chance to make predictions about the scenarios without any physical models or simulations to check their predictions.

The hands-on activity we developed included cases for both a slider-crank and a 4-bar linkage mechanism. Figure 1 shows the physical models that students were provided in class. Students were assigned to work through the activity in groups of three to four people. Each group received an activity worksheet and various 3D printed parts that could be arranged into either a crank and slider or a 4-bar linkage. The worksheet followed the "predict, observe, explain" cycle format. Students were prompted to make predictions about directions of angular and linear velocities or accelerations. After all students in the group stated and wrote down their predictions, they were prompted to reproduce the scenario using the physical model. At this point students discussed what they observed, and wrote down a follow-up explanation of the result using dynamics principles. During the activity, the instructor and learning assistants visited the different groups and asked guiding questions to help the students with the activity. Between each case, the instructor led a class discussion to be sure the students had a firm grasp of the previous cases before moving on to the next case.



(A) (B)

Figure 1. 3D printed rigid body kinematics kits used in the hands-on activity. (A) Four-bar linkage model. (B) Slider-crank model.

Assessment

To assess the results of this activity, students were provided access to a voluntary, anonymous survey asking them to reflect upon the experience. Some of the survey prompts included:

- How would you rank the effectiveness of this activity in learning dynamics?
- The difficulty of this activity was:
- Was this activity interesting and motivating?
- Did this activity improve your ability to visualize other rigid body kinematics questions?

Students answered the prompts with a scale of options such as strongly disagree to strongly agree.

Results

The following Figures 2-5 show the spread of student responses to the survey's prompts. Figure 2 shows that, out of 53 respondents, all but 7 students either agreed or strongly agreed that the activity was effective in learning dynamics.

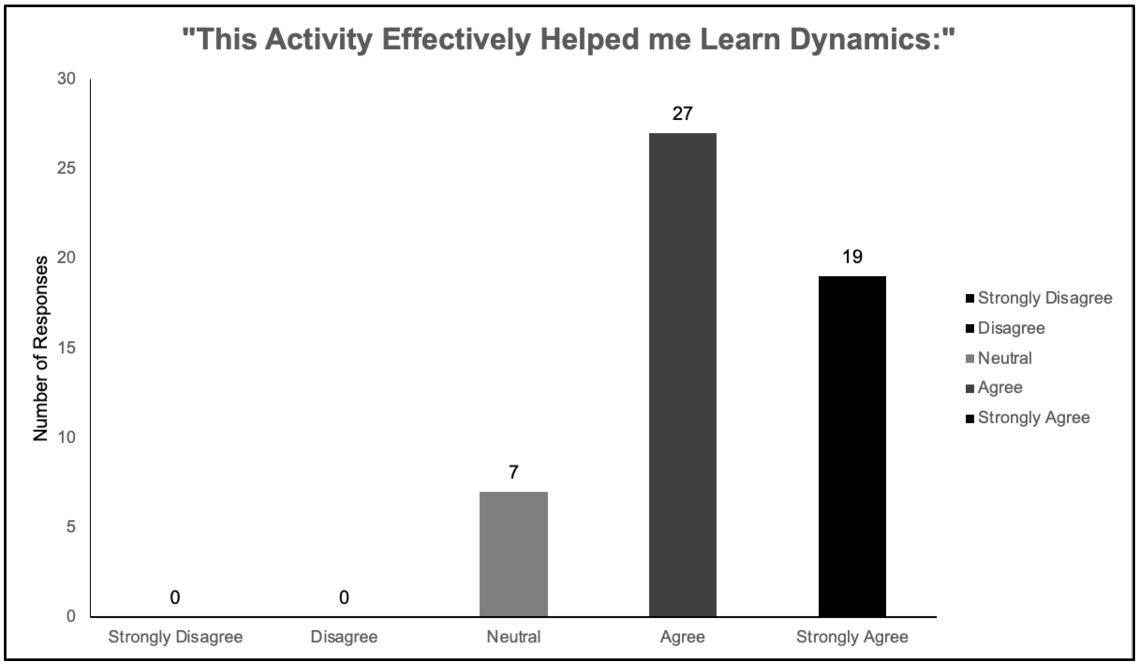


Figure 2. Student survey responses to the prompt "This activity effectively helped me learn dynamics."

Figure 3 shows that out of 53 respondents, 45 students felt that the difficulty level of the activity was "just about right." The remaining 8 responses indicated that the activity was "slightly too easy."

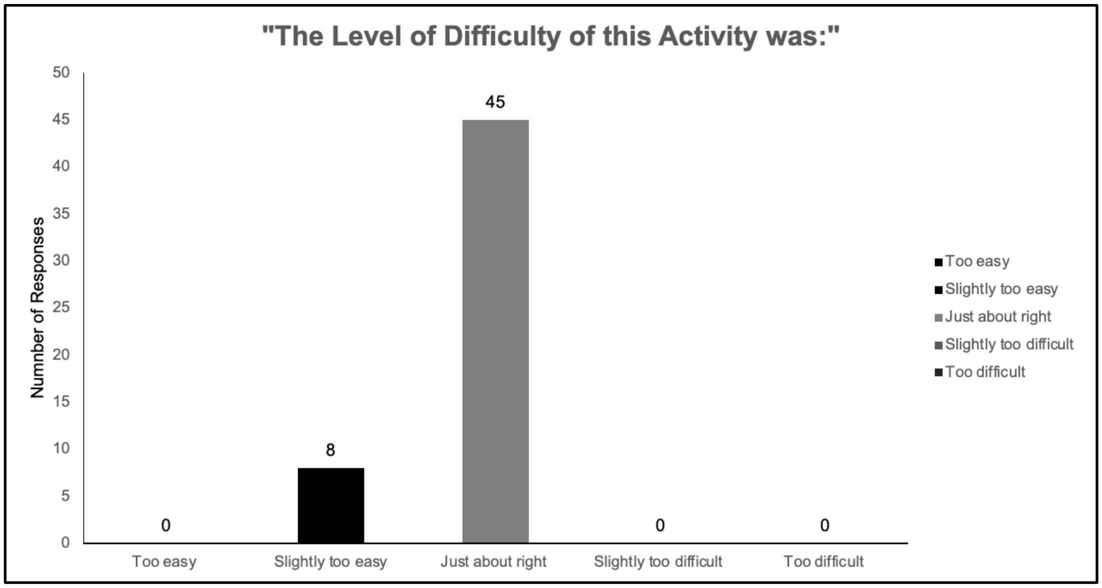


Figure 3. Student survey responses to the prompt “The level of difficulty of this activity was:”

Figure 4 shows a slightly more distributed spread of responses to the prompt “this activity was interesting and motivating.” Eight students felt neutral about this statement while 29 students agreed and 16 students strongly agreed.

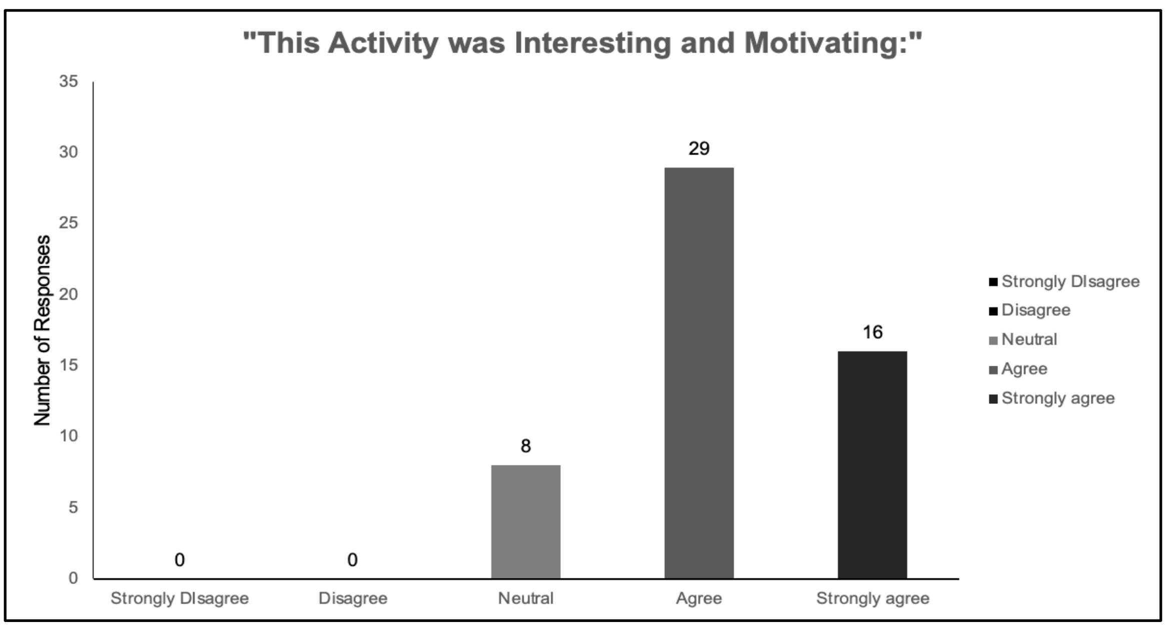


Figure 4. Student survey responses to the prompt “This activity was interesting and motivating.”

Figure 5 shows that only two out of 53 students felt neutral about the activity influencing their ability to visualize other rigid body kinematics problems. The vast majority of respondents either agreed or strongly agreed with the prompted statement.

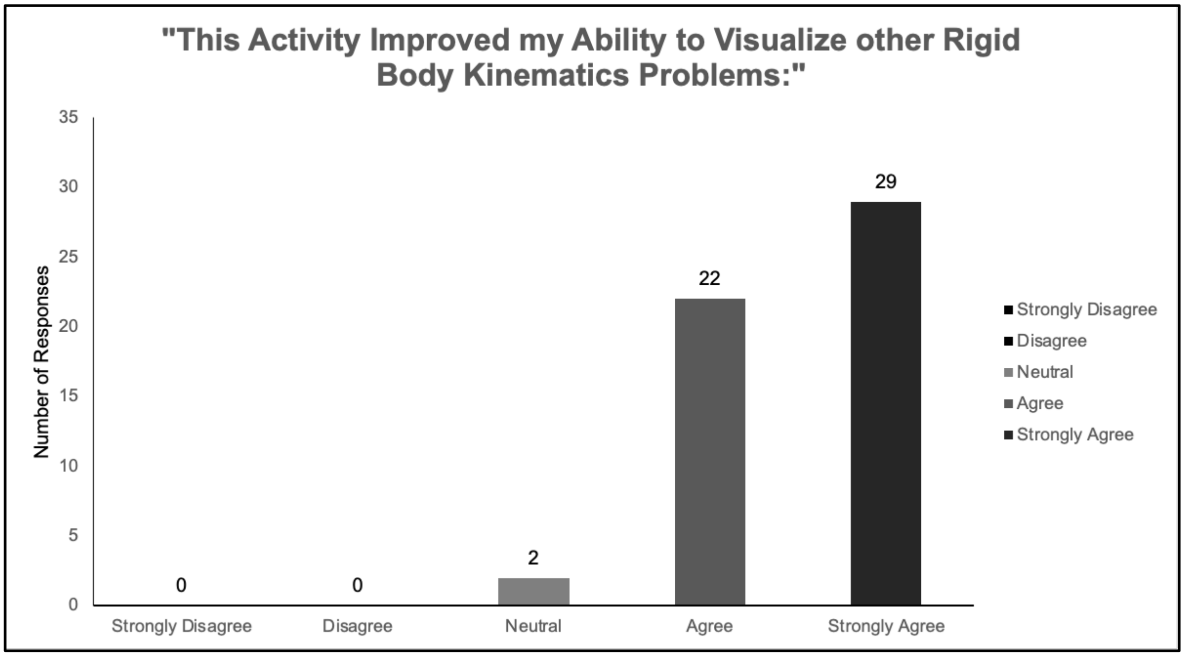


Figure 5. Student survey responses to the prompt "This activity improved my ability to visualize other rigid body kinematics problems."

Discussion

Post-activity feedback suggests that a majority of the students felt that the activity was interesting and a useful tool in introducing rigid body kinematics. Figure 5 shows that a majority of the student responses indicated that the in-class activity improved their ability to visualize other rigid body kinematics problems. The student feedback is significantly encouraging that hands-on activities like this could have a positive effect on their ability to analyze other dynamics scenarios. The presence of a hands-on kit also sparked student engagement and enthusiasm, which are critical components for the development of confidence and comprehension of course material [3].

In our post-activity assessment survey, we also allowed students to share additional feedback or comments. One student said, "I thought this activity was fun in using actual physical things to learn, which helps me a lot more than just auditory/visual." A majority of the comments mentioned that the activity was engaging and fun. Some of the constructive feedback included the mention of improving the conciseness of the worksheet, as well as adding written directions for setting up the kits (only photo diagrams of the proper configurations were provided). One student suggested; "Some more in-depth questions (the TA was very good about prodding our group to continue to think about the problem) could be included at the end to help with understanding beyond the base level." Overall, the trend of student feedback provides encouraging justification to continue development of this activity and the accompanying hands-on components. In the future, we plan to investigate the students' cognitive gain regarding rigid body kinematics through pre and post activity assessments.

Acknowledgments

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