K’NEXing Models to Examples in Engineering Mechanics

Abstract

The transition from Statics to Dynamics is often difficult for students, especially in their sophomore year. Where previously everything was stationary, now the possibility of movement enters into the analysis process. This can be challenging, particularly for visual learners, when asked to evaluate motion using only a two-dimensional, static picture or diagram. The use of informal models and in-class activities have been employed by the authors on a continual basis in the combined statics and dynamics course, and while the statics portion traditionally progresses smoothly, students often comment that it is difficult to understand the motion for the dynamics portion, even with models used in class.

Endeavoring to improve student visualization, and building off of the idea that teaching a concept will further strengthen ones understanding of the material, the engineering mechanics faculty incorporated a student project to create a K’NEX model which demonstrates kinematic principles presented in class. Students not only had to design a physical model, but also had to include a worksheet with a problem statement, an associated diagram of the model, and a complete solution page.

The original intent of the project was to deepen the students understanding and to reinforce the concepts of kinematic motions – Translation, Rotation, Rotation About a Fixed Axis, and General Plane Motion. After two semesters of refining the project, the professors intend to incorporate previous semesters’ projects into in-class learning activities; each group of students (generally between four and six) will be given a model along with the worksheet and work through a solution for position, velocity or acceleration dependent on the question addressed in the problem statement. There are three classes devoted to these dynamics principles, and the instructors will incorporate a different in-class learning activity into each lesson. It is the authors’ goal to increase student comprehension of dynamic concepts by allowing them to do more than simply observe the motion (as was done for previous semester in-class activities); students will create the motion utilizing hands-on dynamic models which they will construct in class and then solve for the variables of kinematic motion.

Most engineering students are visual, sensing, active, sequential and inductive learners[1] while most teaching is verbal, intuitive, sequential and deductive[2]. In an effort to change the teaching style to address the students preferred learning styles, the K’NEX projects and subsequent in-class worksheets address visual, sensing, active and inductive learning styles. To assess student learning, comparisons will be made of students with no model usage, students who created models but did not utilize the model/worksheet in-class activities, and those students who not only created, but also were exposed to hands-on activities using models during the dynamic lessons. Assessment of actual and perceived gains in topic comprehension will be performed via grade distributions on dynamics tests versus previous semesters, Likert surveys of students, student comments, and student self assessment of concept understanding versus previous semesters. Comments are summarized from two sections of students in Fall 2009 (70 students total), and exam averages compared Fall 2009 with four previous semesters.

Educational Atmosphere

Engineering Mechanics at Florida Gulf Coast University is a combined 4 credit hour Statics and Dynamics course which students typically take during their sophomore year. Offered as one of the interdisciplinary courses, the roster contains students in bioengineering, civil engineering, and environmental engineering. Topics in statics and dynamics are discipline specific in various courses offered in the curriculum at the junior and senior levels. The majority of engineering courses at Florida Gulf Coast University are offered in the integrated lecture-lab format. This means that for a four credit course, class meets twice a week for 2 ¾ hours each time. Because of the extended class period, presenting the necessary material in an engaging format and not overloading students on new concepts requires additional considerations over what might occur in a course that has 50-minute sessions three times a week.

Dynamics accounts for approximately 40% of the course content, and roughly 42% of the course grade. Compared to a traditional course offering, this course meets the equivalent of 84 -50 minute lessons of which 34 are devoted to dynamics; this is only 8 lesson less than a full semester of 42- 50 minute lessons of dynamics. Engineering Mechanics is divided into five sections, each with an associated exam. Sections are varied in length and exam weight is adjusted accordingly. Dynamics is covered in sections four and five, with the first of these being kinematics and the second kinetics. Three class periods are utilized to present the kinematic concepts of translation, rotation, and general plane motion. The concepts are reinforced as a review session with worksheets in the fourth class, and the fifth class period of kinetics is an exam. The combination of a compressed schedule and integration of movement into situations that were previously stationary results in many students feeling overwhelmed with the subject. For many of the students, particularly the visual learners, the confusion stems not from the calculations, but rather from the determination of what motion is actually occurring. Motionless 2-dimensional figures were satisfactory for illustrating reactions and forces for static conditions but often prove to be ineffective in conveying kinematic principles, particularly in the introductory phase of learning.

The concerns and frustrations exhibited by the students prompted the authors to consider potential measures to resolve these concerns. Three levels of activities were developed to assist with these concerns.

Class Evolution

Initial offerings of the course augmented the traditional lecture with worksheet examples that were completed either as an entire class or by small groups of individuals. Subsequent offerings maintained these worksheets and class activities and gradually expanded upon them. The first addition was that of a K'NEX project. Students were required to design a physical model which demonstrated kinematic principles presented in class, but also had to include a worksheet with a problem statement, an associated diagram of the model, and a complete solution page. The most recent incarnation of the project also requires pictures from multiple angles as well as a short video demonstrating model movement. The second addition involved the incorporation of these

K'NEX models into classroom activities – by two separate means. The first technique was for the instructor to create models that would mimic worksheets already used in the course; the second was to incorporate previous student projects into new in class activities. The following sections present examples of each of these course additions.

Example K'NEX Model and Worksheet

Rotation about a fixed axis (RAFA) is introduced during the first kinematics class period. This particular concept can be covered in a number of ways, the instructors for this course choose to use RAFA sticks as the method of choice. As with all concepts in the course, introduction of the theory and equations is linked with example problems presented on worksheets. For this particular concept, the worksheet problem is based on a ferris wheel. Figure 1 presents both the worksheet problem, as well as the associated diagram.

Problem 4: The ferris wheel shown rotates counterclockwise about point O such that at a given instant the acceleration of point A is $a_A = -80\boldsymbol{i} - 60\boldsymbol{j}$ fps^2. At this instant, what are the tangential and normal components of the acceleration of point B? What is the velocity of point B?

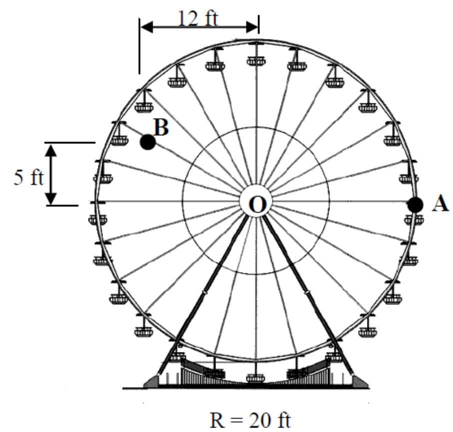


Figure 1: Worksheet Problem Statement and Diagram for Rotation About a Fixed Axis

The motion for this particular problem is not complicated, and the diagram alone or in combination with student personal experience is likely sufficient to understand what is occurring. The benefit of introducing a model in this situation is less about comprehension of the problem itself but rather more about the recognition of RAFA sticks and their potential use in problems. The associated model, two different views of which are presented in Figure 2, provides multiple opportunities for demonstrating the concept of a RAFA stick.

Linking this to the worksheet example can assist in the initial critical step of constructing kinematic diagrams from which the equations, and ultimately the problem solution derive. The hope is that if this process can be mastered in the early stages of comprehension it becomes rote as more complex situations are encountered. As additional reinforcement of this intent, the ferris wheel model was re-visited when discussing relative velocity by considering the movement of the "chair" about its hanging rod as one RAFA stick and the rotation of all of the hanging rods about the central point as a second RAFA stick. Combining these can result in the velocity of an individual sitting in the chair relative to the ground.

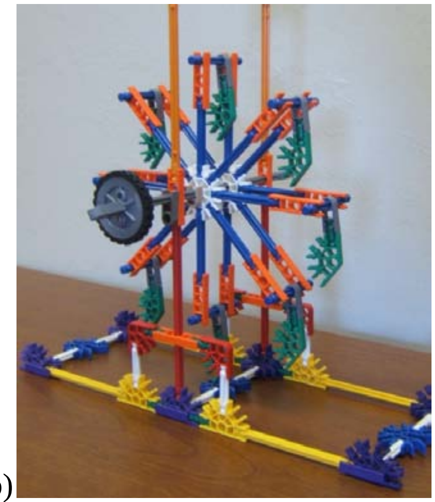
a)  b) 

Figure 2: a) Front view and b) Angled view of K'NEX Ferris Wheel Model

Example Initial K'NEX Project Used in Class

Figure 3 is an example of one of the K'NEX projects submitted the second semester a dynamics project was a requirement of the course. The students that created this project were not exposed to previous projects or models in the classroom. This was also one of the project / handout combinations that was incorporated for use in the most recent offering of the course. Some of the reasons this project was chosen over others was the relative ease in constructing the model, the various kinematic motion illustrated and the clarity and professionalism of the worksheet.

A wheel with radius 2 meters rotates as the piston moves from A to B. Classify the types of motion, find the velocity of the piston, the angular velocity of the rod, and the angular velocity of the wheel. Velocity of point C is 24m/s.

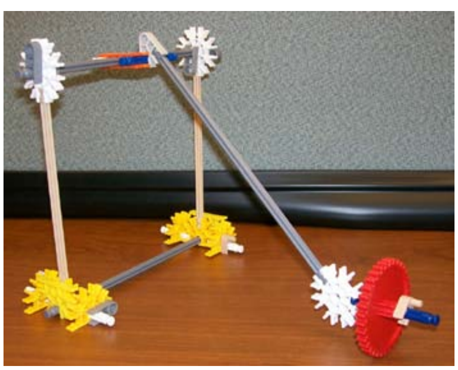
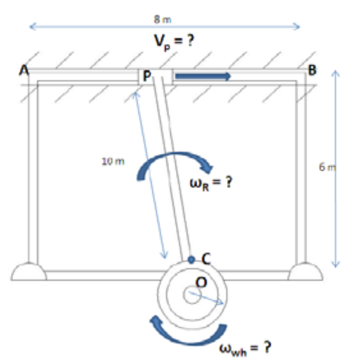
a)  b) 

Figure 3: a) Photograph of Model and b) Example Worksheet Created by Students

Because we used this K'NEX dynamic project submission as an in-class activity for the most recent course offering, both the students and the instructors benefited from improved submissions. The instructors and students found that while the models used were simple to construct, the motion was not smooth or students had difficulty constructing the model based on the picture provided. As a result, for the most recent semester students were required to include at least three images/pictures of their model. Several students also created more straightforward models that clearly demonstrated the motion and developed worksheets that were straightforward and more closely mimicked worksheets they had seen in class.

Example Recent K'NEX Project

Portions of a dynamics project submission from the most recent semester are illustrated in Figures 4 and 5. In addition to what is included in the figures below, the group also provided a total of four pictures of the model taken at different angles, a clearly worked solution, and a short video demonstrating the model movement. Though not presented here, some groups took the initiative to create a model that was representative of movement relative to their discipline. As an example, one group composed of all bioengineering students modeled the leg and considered the motion of the foot relative to the hip.

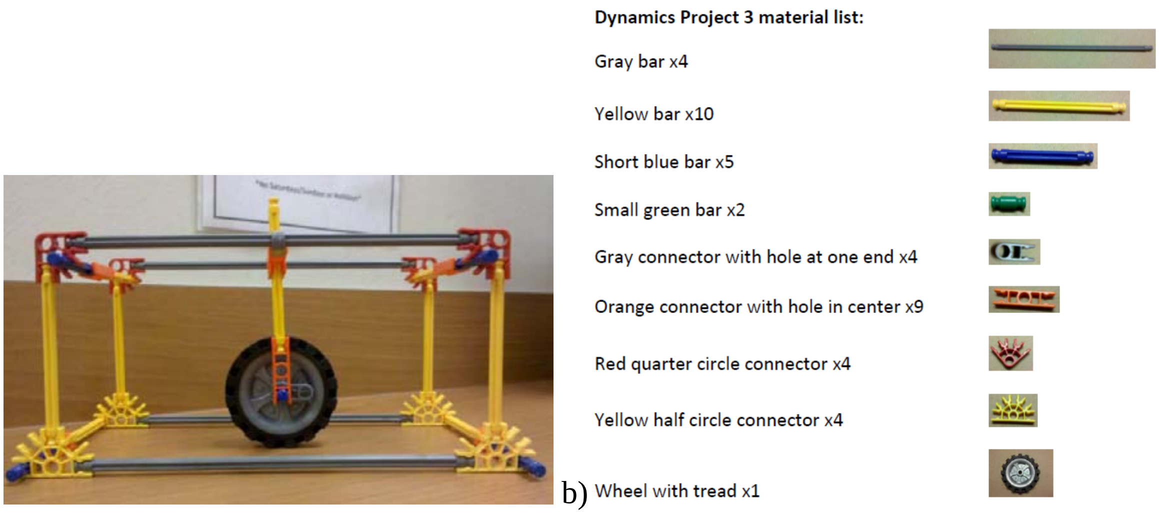
a) 

Figure 4: a) Photograph of Model and b) Parts List for K'NEX Model Developed by Students in Most Recent Course Offering

Worksheet:

A wheel with a radius of 3 meters rotates clockwise as the piston **P** moves toward the right, away from point **A.**

a) Classify motion **b)** Calculate the velocity point C on the wheel given the velocity of the piston **P** is 20 m/s. **c)** Calculate the acceleration of the piston assuming the angular acceleration of point c is 5 rad/s^2.

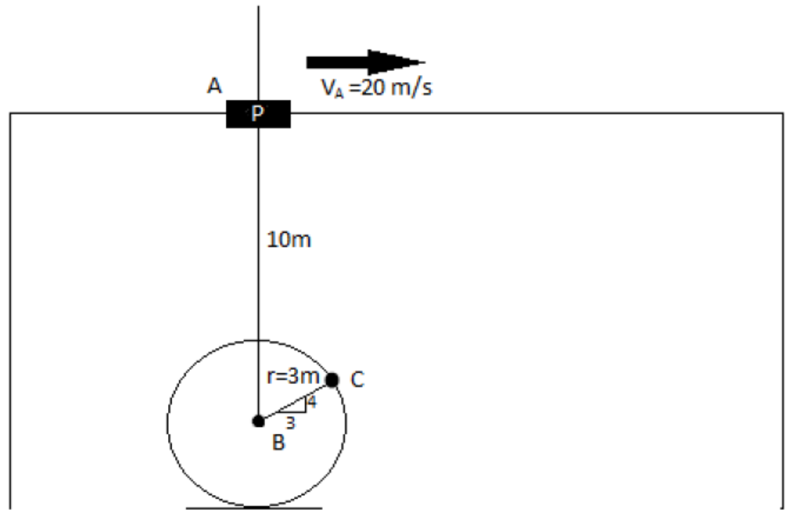


Figure 5: Worksheet for Model Shown in Figure 4a

Evaluation of Effects of Model Inclusion

Differences in Test Scores

Exam 4 tests the students' knowledge of kinematics, including the velocity and acceleration components of translation, rotation and general plane motion. While the exams are different from semester to semester, the same three-problem format has been utilized consistently. The averages on exam for compared with the previous semester were not statistically significant with only one percentage point difference between averages (83.9% this semester vs. 82.8% the previous four semesters). Each lecture includes several problems for a worksheet, so the full two and a half hours are filled between the lecture and student work at the board on these worksheets. Next semester we will remove one of problems from the worksheets and carefully select one of the student projects as a replacement. We are considering having the students build the model prior to class to save precious classroom time to solve the worksheets.

Student Evaluation of Activity

Students from two sections of Engineering Mechanics (N=70) were asked to complete a survey at the end of the Fall 2009 semester on the benefit of the K'NEX in class activity and the K'NEX project. Students were asked to rate the following questions based on a five-point Likert scale (5=Strongly Agree, 1=Strongly Disagree). Table 1 includes the average response for each question.

Table 1: Overall student averages to their responses to questions on the Dynamics survey (N=70). 5=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, 1=Strongly Disagree

Question	**Overall Average**	**Standard Deviation**
I found in-class group activities helpful to my learning	**4.35**	**0.77**
I found the use of models to illustrate motion in dynamics helpful to my learning	**4.26**	**0.82**
I think the K'NEX modeling before Exam 4 contributed to my learning Kinematics	**3.37**	**1.13**
I would like to see models for all example in Dynamics	**3.81**	**0.98**
I found the K'NEX project worthwhile	**3.57**	**1.13**
I believe the K'NEX project contributed to by understanding of Dynamics	**3.48**	**1.08**

Student response was positive for the most part. The highest level of agreement was shown with the relevance of the models to the illustration of motion. Students were more neutral about the project contribution to their learning and comprehension of dynamics topics. Responses from this first evaluation suggest that the visual nature of the models is beneficial while the hands on aspect may not be as critical. One aspect that the instructors are trying to resolve is the fact that the project is actually assigned after students have already taken the kinematics exam. While students could potentially benefit from earlier exposure, the time limits discussed earlier in the paper create a challenge to this modification.

Conclusions & Future Direction

While there was not a direct improvement in the exam scores for the kinematics portion of the course, the instructors feel that the hands on models help demonstrate motions that are otherwise abstract to the students, based on the average in question 2 of Table 1. In the future, the instructors plan to replace one worksheet in each class period with one student project worksheet from previous semesters. The hope is that the models associated with the worksheets will help the students better understand what they are calculating, such as velocity of a point. Assessment of the integrated models and worksheets will continue over the next several course offerings to determine the best application of the K'NEX models, both as in-class activities and as a group project. Included in this assessment will be how the project and in-class activities address established learning styles and specifically, if the project addresses learning styles currently not included in this course.

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[1] Zyno, M.S. 2003. A contribution to validation of score meaning for Felder-Soloman's Index of Learning Styles. ASEE Conference Proceedings, Session 2351.

[2] Felder, R. and L. Silverman. 1988. Learning and teaching styles in engineering education. Engr. Education, 78(7) 674-681.