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Mechanism Animation for Machine Design Instruction

An Interactive Qualifying Project Report:

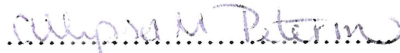
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by



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Approved



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1.0 Introduction

In contrast to days past, when basic engineering skills were learned through hands on experience, literature, and verbal instruction, today's students spend an increasing amount of time in front of computer screens. They have access to a myriad of graphic animations, interactive tutorials, and computational software programs. While the youth of decades past grew up building tree forts and go-carts, modern children are weaned on video games and the World Wide Web. It follows that using an interactive, animation-based approach to motion visualization would fill a need for students and generally suit their background and accustomed learning styles (Wang 2002).

There are a number of potential benefits to using animations in lieu of or as a compliment to static graphics. For use in the instruction of machine design and other visually intensive studies, dynamic images have the advantage of being inherently spatial; they use space to represent space. The same is true of their representation of temporal changes. This is not merely an assumed advantage. Behavioral studies have shown that the "use of spatial relations to express temporal, quantitative, and preference relations was evident in children as young as five, and in children from diverse cultures" (Tversky, Kugelmass, and Winter 1991). Animations can be used to efficiently display complex systems that would otherwise be difficult or tedious to explain. They can draw and maintain student interest and they are especially appealing to visual-spatial learners.

Additional benefits are possible, if not directly from the animations, from the tools they make available. Animations, especially when used in the context of a computer-based tutorial, force students to participate and engage in active learning. Rather than simply looking at a picture of a given mechanism, the student can view its entire range of motion, control its speed and viewpoint, and, in many instances, manipulate system variables to test cause and effect scenarios. In this manner, “animations and interactive simulations of mechanisms can provide insight and understanding previously achievable only through physical experimentation and hands-on experience” (Buchal 2001).

There are many potential advantages to using animations instead of static graphics and their use has greatly proliferated throughout the last decade. However, some educators are wary of this trend. Many are concerned that the use of animation in a curriculum will actually distract students from learning key concepts, especially when used inappropriately or excessively (Rieber 1996). When not designed properly, dynamic graphics can overwhelm students with undue processing demands, making it difficult to grasp the intended concepts. On the opposite extreme, it is also possible to underwhelm students by presenting information in such a manner that no active effort is required on their part. One study found that “students were more prone to develop scientific misconceptions from the animated material” (Rieber 1991).

The use of animated graphics in education has been a controversial topic throughout the past several years. Numerous studies have been conducted to discern whether or not animations do in fact foster learning. To that end, an animation-based

tutorial was created and will be used in part to assess the value of animations with respect to static graphics, specifically for machine design education. The active models used to create the animations were also provided for use as in-class demonstrations or manipulation by students experienced with Pro-Engineer.

In addition to the online tutorial and related models, an active fourbar model was created and configured to compliment the *Hrones and Nelson (H&N)* atlas of fourbar coupler curves (1951). Using Pro-Engineer family tables, the varying assemblies were created and organized in a manner easily understandable and accessible to students, regardless of modeling experience or ability. In addition to animating the linkage motion, the Pro-Engineer model provides detailed analyses of the general motion solutions contained in the *H&N*.

2.0 Background

To design an effective tutorial, in-depth research was conducted into related studies, multimedia design, survey techniques, and concept evaluation. In addition to literature research, two professors from the WPI Mechanical Engineering Department were interviewed to determine which machine design topics their students routinely struggle with. A survey of past machine design students was also conducted to correlate topics students felt they struggled with compared with those named by their professors.

2.1 Related Studies

In a 1984 study, ChanLin tested the ability of 8th and 9th grade physics students to retain and apply knowledge of basic physics and force concepts following three separate treatments. The first group received a text-based tutorial. The second received the text tutorial with additional static graphics. The third received a tutorial in which animations were included in place of the static graphics. The students were administered identical posttests that probed for spatial ability in addition to descriptive and procedural knowledge following their respective treatments. Results indicated that the use of animations versus static graphics benefited students with high spatial ability, but showed no effect for students with low spatial ability (ChanLin 1984).

In 1988, Back and Layne conducted a study to determine the effects of using text, static graphics, and animations to teach the concept of average speed to elementary school students. The three treatments were performed, and subsequent testing revealed that the students given the animation and text tutorial consistently scored five percent higher than their counterparts. Though statistically significant, the authors felt that such an increase would not justify the time and money required to create the animated tutorials (Back and Layne 1988).

Wong took a slightly different approach, hypothesizing that good animations are better than good static graphics, but that poorly constructed animations are worse than well-designed static graphics. Following his 1994 study, Wong concluded that in teaching abstract statistical concepts, good static graphics are indeed better than poorly

designed animations, but he observed no difference in performance for students exposed to static and dynamic graphics of equal quality (Wong 1994).

In 1997, Hutcheson extended the work done by Wong by adding voice narration to Wong's animated tutorials and improving his quiz questions. She then administered the tutorials to undergraduate students at Carleton University. The students were motivated by a \$10 participation fee and the promise that they would be learning concepts pertinent to a required statistics course. Quiz accuracy, tutorial completion time, quiz completion time, time spent per tutorial page, and the number of tutorial pages accessed served as the dependent measures for this study. The results indicated no statistically significant differences between treatments with respect to any of the dependent variables.

Though none of the studies discussed produced results in favor of dynamic graphics, the authors were unanimous in their assertions that the shortcomings may lay not with the animations but in the tools used to evaluate them. Numerous recommendations were offered, ranging from alternate topic suggestions to advise on how to better phrase posttest questions; all were considered in the design of this tutorial, though many were not feasible due to constraints on available time and resources.

2.2 Techniques for Effective Media Use and Design

The cognitive learning process has been one of intensive psychological study, and from this have sprung two theories that can be used to guide the design of effective instructional multimedia. The dual channel assumption states that human cognition has two distinct channels for representing and manipulating knowledge: the visual-pictorial and the audio-verbal. Each channel has a limited capacity, but both can process independent information simultaneously. The active processing assumption states that “meaningful learning occurs when learners engage in active processing within the channels,” which includes selecting relevant words and pictures, organizing them into mental models, and integrating the information from both channels with the appropriate prior knowledge (Mayor 2002). Active learning is therefore more likely to occur when corresponding verbal and pictorial information is working in memory at the same time. Based upon these long standing assumptions, Mayor devised the following eight principles:

Multimedia Principle. Words and pictures conveying the same information may seem redundant, but deeper learning is achieved through words and pictures than from words alone.

Contiguity Principle. Words and pictures should be presented simultaneously versus successively. This increases the chance that both words and pictures will be active in memory at the same time, while reducing the required lesson time by half.

Coherence Principle. Adding interesting but irrelevant information does not increase learning and, in some cases, actually hinders it. Sensational material draws attention from causal explanations and may serve to overload one of the cognitive channels. For this reason, extraneous words, sounds, and video images should be omitted (Renninger, Hidi, and Krapp 1992).

Modality Principle. Students learn more from the combination of pictures and narration than from pictures and text. While text is another form of words, it is still processed by the visual-pictorial channel, and may cause cognitive overload (Mayor 2002).

Redundancy Principle. The combination of narration and pictures works best without additional text. Though this would allow the student to choose a verbal or written explanation, it will likely cause a split-attention effect (Sweller 1999).

Personalization Principle. Students perform better when presented with information in the form of a social interaction. Using a conversational narration, adding personal comments, and replacing the third person perspective with that of the first or second will increase interest and active learning.

Interactivity Principle. Allow some control over the presentation rate. Including prompts such as “Click here to continue” encourages cognitive processing.

Signaling Principle. Research has shown that students are predisposed to selecting information based on physical characteristics such as color and motion. For this reason, it is important to incorporate signals or cues to draw attention to key points. Do not add information - simply add emphasis where appropriate (Rieber 1996).

These principles serve as guidelines for the design of effective multimedia, but they do not cover when its use is appropriate. Dynamic graphics can be a powerful instructional media, but only when used to portray inherently temporal-spatial information. They are particularly appropriate to show mechanical motion and trajectories, as well as events that are otherwise invisible (Rieber 1991).

2.3 Data Collection Methods

Initial research identified mechanical motion as a particularly appropriate use of animation-based multimedia. Therefore, students in the machine design courses at WPI were selected as subjects and the interactive tutorial was tailored to illustrate the mechanisms important to their curricula. The course syllabi and text provided a comprehensive list of the topics to be covered (Norton 2001). Kinematics of Mechanisms (ME3310) details the synthesis and analysis of linkages, cams, and gear trains while Dynamics of Machinery (ME3311) tackles dynamic force analysis, balancing, and engine design. These topics were discussed at length with the course instructors, who were asked to indicate which topics they felt their students routinely struggled with and which they felt could be most effectively represented using 3D dynamic models. Professors Norton and Moon cited the spatial relationships between moving mechanism components to be their foremost concern and each indicated a number of models they felt most appropriate to model for the students. Professor Norton expressed an interest in having two pick-n-place mechanisms modeled (Norton 2001, figures 2-14 and 3-7), while Professor Moon sought to increase student exposure to the numerous variations of the simple fourbar mechanism.

Past students were then surveyed to determine which topics they felt were most difficult to learn and in which topics they felt a 3D dynamic model would have been most useful to them. Prior to constructing a questionnaire, the proper means of survey development as well as alternate data collection methods were researched. Surveys generally take the form of mailed questionnaires, telephone surveys, or personal

interviews, depending upon a number of factors including time pressures, available resources, and topic sensitivity. In this case, rapid response time was a priority and available resources were minimal. It was also important to ensure anonymity as many of the students in the survey group remained at WPI and some of their answers may have reflected upon existing professors. Given these conditions, it was decided that a questionnaire would be posted online, and email requests for participation would be sent to all of the students who were registered for ME3310 or ME3311 during the 2002-03 academic calendar. Once the questionnaires were completed, they were to be submitted electronically so that individual responses could not be traced back to the student. The introductory and follow-up emails as well as a hard copy of the questionnaire are in the Appendix.

The questionnaire began with a few background questions and then moved on to request that the students rate the difficulty of the topics covered in ME3310 and ME3311 and their understanding thereof. They were also asked to select which of those topics they felt could be best demonstrated using 3D computer simulations. The questionnaire concluded with a few open-ended questions about their level of mechanical experience prior to taking the class and what effect, if any, they believed it had on their performance within the class.

After three weeks, 16 of the 92 students had responded. Time constraints dictated that the project had to move forward. Not enough data was collected to conduct a rigid statistical analysis, but the responses submitted proved insightful. The complete student response set is included in the Appendix . Overall, the responding

students rated the acceleration and velocities of linkages to be the most difficult topics covered in ME3310. They also felt that they had a less than adequate understanding of those topics. Based upon this information, and the fact that linkage motion readily lends itself to animation, the acceleration and velocities of linkages were chosen as the focus of this study. The models selected by Professors Norton and Moon were also linkages, so the desires of both the students and professors could be met simultaneously.

2.4 Topic Development

While determining the effectiveness of the online tutorial is beyond the scope of this project, a thorough understanding of educational assessment techniques remained necessary in order to develop constructive prediction questions to include in the tutorial. The subject of academic assessment is as broad and diverse as the topics it seeks to appraise, but two particularly relevant documents came to light: the Force Concept Inventory (FCI) and the Mechanics Baseline Test. Each document contains a series of questions specifically designed to probe student understanding of Newtonian physics concepts at the most fundamental level (Hestenes et. al. 1992). The Bloom Taxonomy of Educational Objectives was also useful in refining the form of the questions posed such that they elicit a student response on the level desired by the researcher (Bloom 1956).

2.4.1 Force Concept Inventory

The Force Concept Inventory (FCI) is purely conceptual and appropriate for use as a pretest/posttest for students of all educational backgrounds. It consists of 30 multiple-choice questions and seeks to force choices between Newtonian concepts and commonsense alternatives. In this sense, the FCI does not test intelligence but rather probes the belief system of the subject to determine whether it is based in Newtonian principles or commonsense hypotheses. Each question is designed to investigate a specific misconception, and those focused on the elements of kinematics pertain directly to the velocity and acceleration characteristics of linkages presented in the tutorial. The misconceptions of note include a failure to differentiate between position, velocity, and acceleration as well as a lack of appreciation for the vectorial nature of velocity and acceleration.

In addition to administering the FCI and analyzing its results, the authors also conducted detailed posttest interviews in order to determine the thought processes that lead students to their answer selections. Through the interviews, it was determined that students routinely selected Newtonian responses, but for non-Newtonian reasons. It was also common for students to misinterpret questions by skipping over a vital word within the sentence. This evidence advocates the necessity of designing questions that not only target the specific misconception of interest, but that also provide a response selection from which the student thought process may be discerned. It is also crucial to give adequate focus to keywords within the text by altering their font or otherwise drawing attention to them (Hestenes et. al. 1992).

2.4.2 The Mechanics Baseline Test

The goal of the Mechanics Baseline Test is to assess qualitative understanding through conventional, quantitative methods. Its distracters include typical student mistakes in place of the commonsense alternatives offered in the FCI. Its questions are predominantly calculation-based versus conceptual, and for this reason, its use is most appropriate when working with subjects that have had at least some formal physics instruction. The kinematics concepts covered by the Mechanics Baseline Test include linear motion (constant and average acceleration, average velocity, and integrated displacement) as well as curvilinear motion (tangential and normal acceleration). The Mechanics Baseline is often used as a posttest compliment to the FCI.

2.4.3 Bloom Taxonomy of Educational Objectives

While most instructors aspire to develop and assess high-level critical thinking within their students, testing has been traditionally limited to pinpointing low-level content knowledge (Nuhfer 2003). As a response to this trend, Bloom developed his six Levels of Reasoning, which are summarized in Table 1 alongside a description of each level and the form of questions most likely to elicit a response at the given level.

Reasoning Level	Description	Prompt
1. Recall	Remembering terms, facts	"Who...?" "What...?"
2. Comprehension	Understanding meanings	"Explain." "Predict." "Interpret."
3. Application	Using information in new situations	"Calculate." "Apply." "Demonstrate."
4. Analytical	Identifying organization and patterns	"Distinguish." "Compare." "Contrast."
5. Synthesis	Generalizing or creating new ideas from known sources	"Construct." "Develop." "Formulate."
6. Evaluation	Discriminating and assessing the value of evidence	"Evaluate." "Justify which is better."

Table 1: Levels of Reasoning (Bloom 1956)

Recall is the most common focus of educational assessments and includes questions meant to probe basic memorization skills as they pertain to a select group of terms or facts. Though familiarity with terms and facts is a necessity in any field, if only to facilitate communication, the tutorial is aimed at higher-level learning.

Comprehension differs from recall in that it requires not only a familiarity with a subject, but an active understanding of the subject matter. A student who comprehends a concept will not only be able to recite it, but also explain it to another student by transposing the concept into his or her own words. One of the main goals of the tutorial is basic comprehension and, to that end, the students will be presented with dynamic mechanisms and instructional text that will convey not only what the mechanism is and does, but also why and how this is accomplished.

The application of information is what marks the bridge between the pure sciences and engineering. For research scientists, the acquisition of data is the main objective and most often takes the form of result sets from carefully designed and executed laboratory experiments. Engineers, on the other hand, employ gathered data as a tool to develop solutions to the problems presented to them. Through the prediction questions in the tutorial, students will be instructed to take what they learn from early models and apply it to more complex mechanisms encountered further on.

Analytical skills can be described as the ability to draw conclusions from a given set of data by recognizing organizational structures and patterns. Linkage analysis plays a dominant role in kinematics instruction and includes the examination and detailed calculations of link position, velocity, and acceleration. With regards to the

tutorial, students will be required to distinguish the position, velocity, and acceleration characteristics of a series of simple mechanisms.

The development and synthesis of a problem solution marks the work of a mechanical engineer. Though linkage synthesis plays a vital role in kinematics, its assessment requires an open-ended evaluation that is beyond the scope of this project. For that reason, the level of reasoning that includes synthesis will be disregarded at this time.

The sixth level of reasoning proposed by Bloom is evaluation, the process through which a proposed or existing solution may be appraised. Questions prompting a response at this reasoning level are also beyond the scope of the tutorial, though the prediction questions that require the student to justify his or her response selection touch upon this topic peripherally.

2.5 The Companion Website

Shridar Kota is a kinematics professor who believes that before students can create novel mechanisms, they must first understand the functionality of those already in existence (Kota 2001). He first sought to do this by “bringing out the intuitive appeal inherent to mechanical motion” through the creation of an interactive web-based tutorial to supplement his conventional design text (Erdman 2003). The Companion Site shadows the text, *Mechanism Design: Analysis and Synthesis, 4E*, on a concept-by-concept basis and includes a mixture of text instruction, static and dynamic illustrations, and a series of interspersed quiz questions (Kota 1994). The included animations are primarily basic linkages used to demonstrate concepts such as straight-line motion and dwells, though some increasingly complex systems are also introduced. Each animation is shown in two views, an isometric view and the projection that best shows the area of interest. There is also a series of buttons below each graphic that allow the student to replay each segment as many times as desired, but he or she does not have any additional control over the presentation rate or perspective.

The Companion Site has received nothing but positive feedback from the students first introduced to it, though the comments were in response to broad-based questions pertaining to the students’ overall satisfaction with the course during which it was presented. The students felt that their knowledge retention and understanding of basic kinematics concepts was enhanced by their experience with the Companion Site, but no tests were administered to determine whether or not the website increased actual learning.

3.0 Methodology

The following sections detail the progression of the tutorial from the vague concept of animated instructional media to its finished form. The reasoning behind the selection of format, individual models, and topic refinement is discussed in depth, while the process used to create the media is covered briefly.

3.1 Media Selection

The first step in narrowing the field of possible solutions was to decide what form of instructional media would be most effective given the resources at hand. The following section includes a description of each of the four options considered as well as a discussion regarding the reasoning behind the ultimate decision to construct an interactive online tutorial.

The simplest method of conveying information would be to do so through a series of looped .mpeg clips that the professor could show during class. The animations would demonstrate the relevant motion characteristics of a given mechanism while the professor offered complimentary verbal explanations and drew focus to the important aspects of the motion. The professor would also have the option of engaging the students in an active discussion by posing questions about the various animations and related topics.

A variation on the previous method would be to provide the professors with active models. This would allow the professor to manipulate system variables such as link length and position as well as driver characteristics. The model would need to include some constraints governing allowable manipulation, but the WPI kinematics professors are experienced Pro-Engineer users and would require minimal instruction as to the range of useful mechanism configurations. The benefits of this method over the last include the addition of cause and effect demonstrations.

Another option was to present the animations by incorporating them into an online tutorial accompanied by text or narrative explanations. This would force each

student to actively participate in the lesson while providing the students with the opportunity to progress at a rate of their own choosing. Review questions and responses could be incorporated into the tutorials. This would serve to direct student attention to important lesson topics and provide the student with feedback as to the extent of his or her knowledge and understanding. In this manner, the professor could also track the progress of the class as a whole in addition to pinpointing struggling students in need of additional instruction. The drawbacks to this implementation, when compared to the lecture-based presentation of the material, include limiting questions to a closed-ended format and restricting feedback to a set of predetermined responses based on common student misconceptions.

In an effort to increase student interaction and active learning, the authors also considered presenting the students with text or narrative instruction coupled with a set of active models. Instead of being limited to passively viewing the animations and interacting with the question and response portion of the tutorial, students would have virtually complete freedom in terms of manipulating viewpoint and presentation characteristics as well as varying the mechanism. Unfortunately, many of the students who enroll in ME3310 and ME3311 have little or no experience using parametric modeling software such as Pro-Engineer. Intensive instruction would be required for unfamiliar users, and the time demand on students would increase dramatically. The models would also have to be extremely robust. Common student mistakes would have to be anticipated and planned for to ensure that variable combinations resulting in physically impossible models could not be entered.

In order to maximize the instructional value of the model animations while still setting attainable project goals for the time and resources allotted, it was decided that a combination of the above options would be pursued. An interactive web-based tutorial would be created, including text-based instruction, mechanism animations, and prediction questions and responses. The decision to make the tutorial text-based versus narrative-based violates the dual-channel principle, but was necessary as the required audio equipment is not readily available in the WPI computer labs at this time (Mayor 2002). The active models used to create the animations would also be saved on CD and distributed to professors and students by request. The instruction sheet accompanying the CDs would give professors the option of using the animations as demonstrations in class and providing motivated students with the opportunity to further explore the mechanism motions in a more in-depth manner.

An additional fourbar model would be provided for use alongside the H&N atlas (Hrones and Nelson 1951). This would provide the students with a simple interactive model with which to become familiar with the parametric software. Family Tables could be used to ensure a robust system in which the students are limited to selecting system parameters from a predetermined list of configurations matching the H&N atlas. This model would also serve as a practical design tool, providing detailed kinematics analysis for a range of possible motion solutions.

3.2 Tutorial Format

Once the decision to incorporate the animations into an online tutorial was finalized, the authors completed a template detailing its layout and basic characteristics. It was decided that students should be able to complete the tutorial during a single lab period (50 minutes) using only the equipment readily available in the WPI computer labs located in the Mechanical Engineering building. A base assumption was then made that five minutes will provide adequate time for students to read the instructional text, consider the animation, make the requested motion prediction, and review the generated feedback for each topic. Ten minutes were allotted for students to read the introduction and concluding remarks. Based upon these initial conjectures, it was decided that eight topic questions would be an appropriate length for the tutorial. If these assumptions are later determined inaccurate, the number of questions can be subsequently readjusted.

The tutorial opens with an introduction. These pages are used to explain the purpose and basic format of the tutorial as well as give a brief overview of the topics to be considered. Instructions on how to manipulate the animations by replaying them, changing the speed, or stepping through motion on a frame-by-frame basis are also provided. The introduction is followed by the body of the tutorial, which is composed of a repeating sequence of instruction, prediction and feedback for each of the eight topics selected. Also included is an option to draw upon a secondary question set that can be used as reiteration for any missed questions. The tutorial body is followed by concluding remarks that reiterate the purpose of the tutorial and request student

feedback on their experience with the tutorial. The following flow chart has been included to better illustrate how the student progresses through the tutorial.

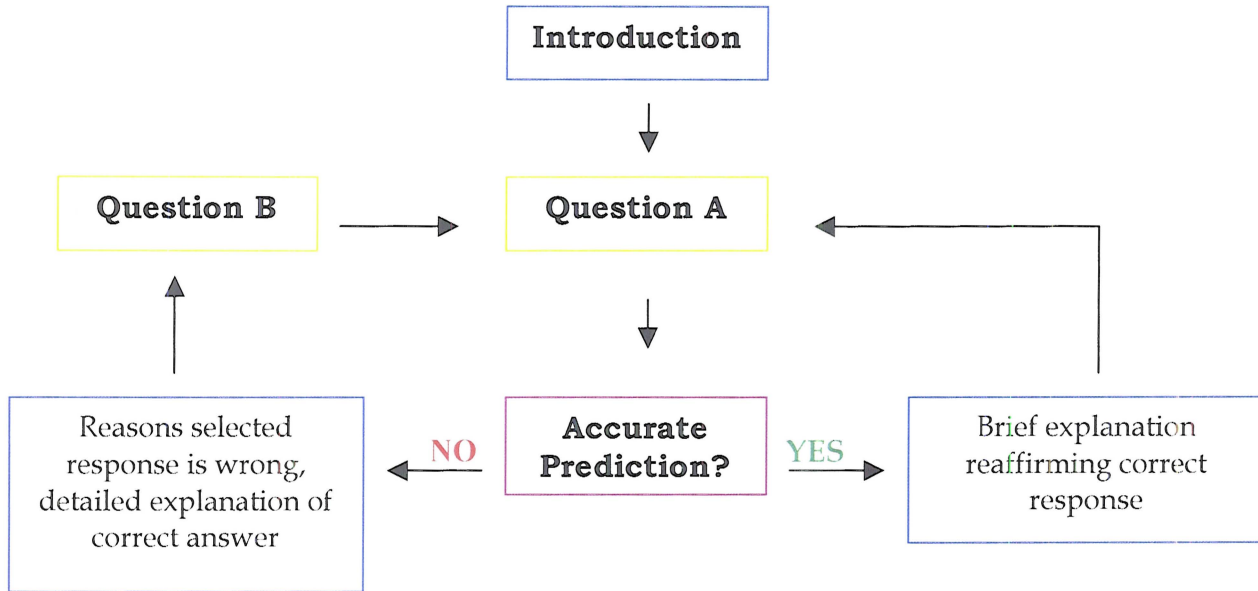


Figure 1: Flow Chart of Tutorial Progression

3.3 Topic Development

The motion characteristics of linkages were chosen as the main topic for the interactive tutorial for two main reasons: 1) information gathered from past kinematics students and current professors pointed to this subject area as being the most difficult to learn and most often misunderstood by undergraduate students and 2) the additional instructional materials provided by the creation of the tutorial and included models will fulfill a purpose beyond the learning experience inherent in their creation. The guidelines for creating effective instructional media also point to mechanical motion as being a particularly appropriate topic to demonstrate using animation.

Having decided upon a major area of study, the next step was to discern the misconceptions commonly held about the selected topic. Student misconceptions regarding the kinematics of Newtonian physics were extensively documented through the administration of the Force Concept Inventory and Mechanics Baseline. The most common mistakes included a failure to differentiate between position, velocity, and acceleration; it was also common for students to overlook the vectorial nature of velocity and acceleration, particularly as it applies to curvilinear motion (Hestenes et. al. 1992). Though not specific to linkage motion, these topics are clearly applicable.

Consideration of the Bloom Taxonomy of Educational Goals further narrowed the focus of the tutorial. Based upon available resources and a desire to facilitate high-order learning, the tutorial questions were designed to elicit responses at the comprehensive, application, and analysis levels. This can be accomplished by beginning with basic motion predictions regarding the position, velocity, and

acceleration characteristics of points on a simple linkage. The student would then continue on to apply what had been learned from the simple mechanism to a more complex one. The tutorial would conclude by directing the students one step further and forcing them to use provided information to compare and distinguish a series of system parameters.

Five mechanisms were selected and modeled, including a simple slider-crank, an offset slider-crank, a double-dwell slider-crank, a simple fourbar, and a six bar pick-n-place mechanism. This particular combination of mechanisms was carefully selected to address the common misconceptions identified by the FCI at the comprehension, application, and analysis levels. By including the H&N Fourbar and the pick-n-place mechanisms, the requests of Professors Norton and Moon were also fulfilled.

4.0 Implementation

The previous sections have detailed the research and planning that went into the design of the online tutorial and related media. What follows is a discussion concerning the physical creation of the tutorial, focusing on two example questions taken directly from the resultant website. A detailed look into the H&N atlas and its complimentary fourbar model is also included.

4.1 The Offset Slider-Crank

The first mechanism considered is the offset slider-crank, shown below in the context of the first question. The slider-crank is the simplest of the mechanisms considered, making it an ideal starting point. This question probes the student's ability to discern the velocity profile of a point when provided with an animated mechanism. Expected errors include mistakenly selecting the position or acceleration profile, which is why those were provided as possible responses. By instructing the student to make a behavioral prediction, this question should elicit a response at the comprehensive level, which is the lowest reasoning level targeted by the tutorial. If the student selects the correct response, he or she will be directed to the page shown in Figure 3, which offers a brief explanation reinforcing the correct answer before continuing on to the next topic.

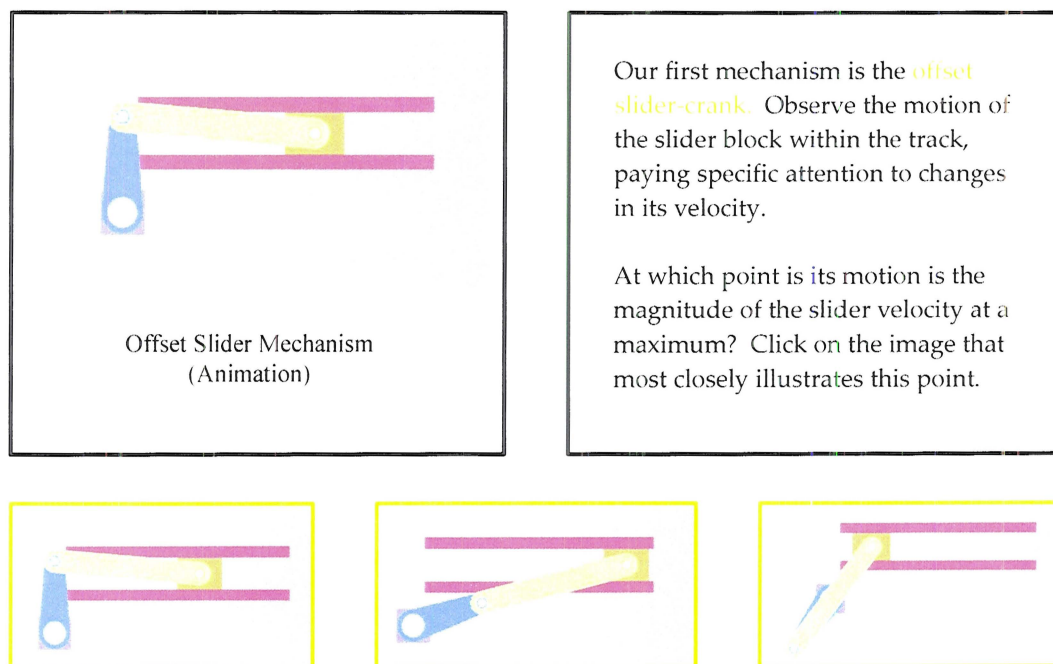


Figure 2: The first tutorial question, utilizing the offset slider-crank to probe velocity misconceptions at the conceptual level.

An incorrect selection would respond with Figure 4, offering a detailed response of the correct answer and a follow-up question before allowing the student to proceed to the next topic.

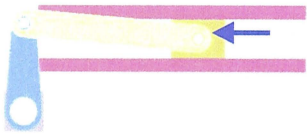
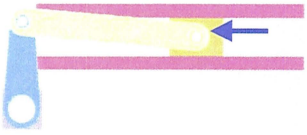
 <p>Offset Slider Mechanism (Animation with Arrows)</p>	<p>That's Right!</p> <p>The animation to the left shows the same mechanism, this time with the velocity vector superimposed on the slider block. The arrow always points in the direction of the velocity, and changes size in proportion to the magnitude of the velocity.</p> <p>You can now clearly see that your prediction was correct, as well as observe the velocity profile throughout the entire motion.</p> <p style="text-align: right;">NEXT</p>
 <p>Offset Slider Mechanism (Correct JPEG)</p>	

Figure 3: Correct responses are reinforced by a brief explanation of the correct answer.



 <p>Offset Slider Mechanism (Animation with Arrows)</p>	<p>Not Quite.</p> <p>The animation to the left shows the same mechanism, this time with the velocity vector superimposed on the slider block. The arrow always points in the direction of the velocity, and changes size in proportion to the magnitude of the velocity.</p> <p>Replay the animation until you are confident that the image below it shows the instance at which the slider block reaches its maximum velocity.</p> <p>Let's try another question with the same mechanism.</p> <p style="text-align: right;">NEXT</p>
 <p>Offset Slider Mechanism (Correct JPEG)</p>	

Figure 4: Incorrect responses are met with a detailed explanation and additional review question.

4.2 The Double-Dwell Slider-Crank

As the student progresses through the tutorial, the mechanisms he or she is presented with continue to increase in complexity. The double-dwell slider-crank, a six bar mechanism with complex motion, is not encountered until the second half of the tutorial. The questions also become progressively more challenging, and the first question posed about the double-dwell mechanism targets the application of knowledge gained from earlier questions (Figure 5). As with the offset slider-crank, the focus remains discerning a velocity profile by observing the motion of a specified point, and the alternate distracter responses include the position and acceleration profiles.

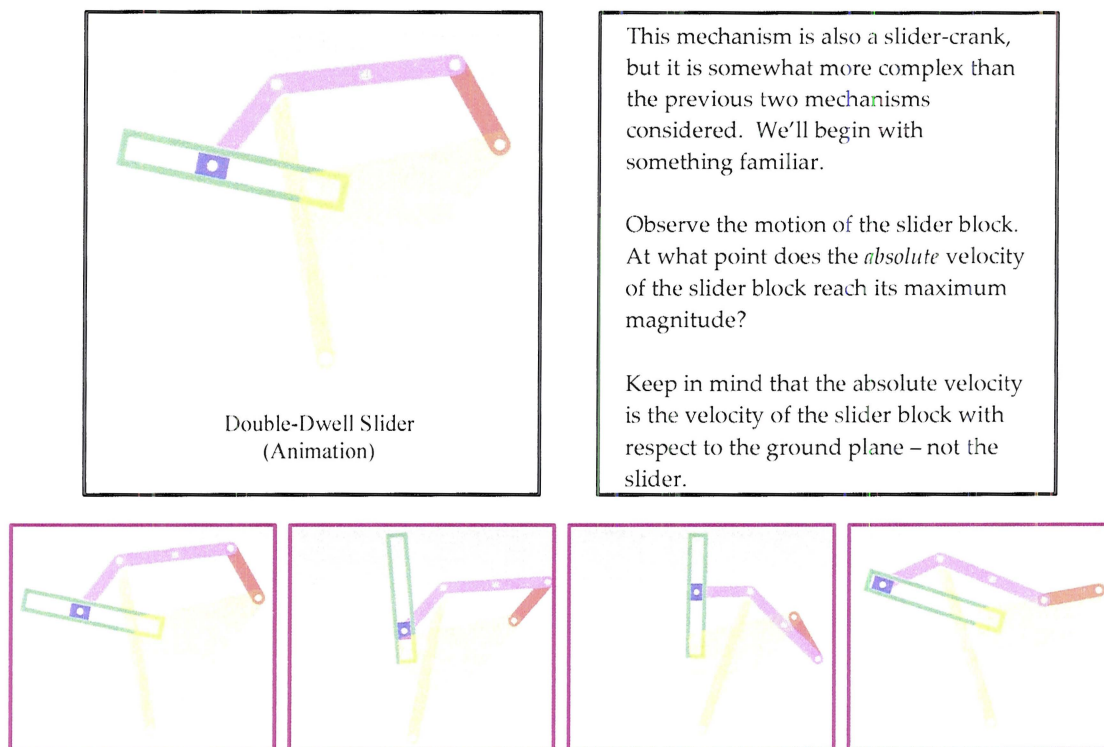


Figure 5: Tutorial question referencing the double-dwell slider-crank mechanism.

The tutorial contains a total of sixteen questions, eight predictions followed by eight possible review questions, encountered whenever an incorrect response is selected. Simple models are presented first alongside lower-level comprehension questions. As the student progresses, he or she encounters increasingly complex models and is challenged by higher-level application and analysis based predictions. Alternate responses featuring the commonplace misconceptions outlined in the FCI and Mechanics Baseline Test are always present as distracters. The completed tutorial, active models, and html code are included on the accompanying CD.

4.3 Hrones and Nelson Fourbar

The Hrones and Nelson atlas of fourbar coupler curves (H&N) was created with the goal of providing “direct aid to designers in selecting a mechanism to produce a desired motion” (Hrones and Nelson 1951). It is composed of a vast collection of dashed displacement trajectories representing the paths of a network of coupler points as they progress throughout the motion of their respective fourbar linkages. Assuming a constant angular crank velocity, each dash represents the movement of the coupler point for a five-degree angular displacement of the driving crank. From these simple graphical models, the velocity and acceleration characteristics of over 7,000 mechanical systems can be calculated with relative accuracy at a glance, providing a wealth of information most useful at the conceptual stage of mechanical design. The information in the Atlas is presented in sets of five charts, each set covering the motion characteristics of a specific linkage. Each page covers ten coupler points, all arranged collinear and parallel to the ground link. For simplicity, the crank length is set equal to unity and the lengths of the remaining three links are varied within the boundaries that dictate a Grashof condition.

The H&N is a well-designed tool for finding approximate solutions to motion problems. A dynamic model was created to provide the visual and detailed information not present in the atlas. Using Pro-Engineer it was a simple task to create and animate a fourbar assembly such that velocity, acceleration, and force vectors are presented explicitly and dynamically. Graphs of this information are also readily available and the data can be exported in spreadsheet form. While a complete set of

fourbar models to rival those in the H&N was not practical within the limits of this project, the information from two pages were selected and reproduced by way of example.

The basic links were created as simple extrusions with a constant thickness and radial profile. The coupler was also formed as a simple extrusion and includes a twenty instance family table that can be used to manipulate the position of the coupler point. The horizontal and vertical distances of the coupler point to the part origin were used as the family table variables and their values reflect those of the selected H&N models. The links were assembled using pin joints in the Pro-Engineer Mechanisms environment. The crank, ground, and rocker links are present in each assembly instance along with a unique coupler configuration. The naming convention used for the assembly instances is based upon five numbers representing the three variable link lengths and the two coordinates used to locate the coupler point (G_C_R_X_Y where G, C, and R represent the respective lengths of the ground, crank, and rocker links and the coupler coordinates X and Y are based off the 0,0 origin). This allows the student to scroll through the table until he or she finds the instance name that corresponds to the values from the H&R.

While many users will be well versed in Pro-Engineer, many engineering students enter ME3310 and ME3311 with limited or no experience using this or similar software. It was therefore necessary to include detailed instructions on how to navigate through the program. The instruction sheet includes the basic procedures for locating and accessing the desired model, manipulating relevant variables with respect to

component substitution, and running assembly and kinematic analyses. Additional topics covered include opening the model, selecting the appropriate configuration, running the existing assembly and kinematic analyses, displaying the velocity and acceleration data in vector and graphical form, exporting data, and printing from Pro-Engineer. The detailed instruction information is contained alongside the models on the accompanying CD.

5.0 Results and Conclusion

The main goal for this endeavor transformed continually as the project progressed through each developmental stage. What began a simple modeling assignment grew into the design of a study to test the relative benefits of static and dynamic graphics. Through the research and development of such methods, the project objectives continued to progress and ultimately resulted in the creation of an interactive web-based tutorial for use in the instruction of kinematics at an undergraduate level. The tutorial is accompanied by a complete set of dynamic models and includes a fourbar compliment to the H&N atlas; this model serves not only as a structured introduction to parametric modeling software, but as a practical design tool.

Though student evaluations were not included in this project, the tutorial was designed with assessment in mind. The presentation and content conform to the guidelines for the creation of effective instructional media, leaving the door wide open for comparative testing with traditional methods of instruction. The prediction questions were also tailored to draw out student misconceptions and false reasoning, making it possible for instructors to track student progress or evaluate the reasoning level of an unfamiliar group of students. As the format, models, and html code are included, it is even possible for a professor to continually adapt and extend the tutorial to include topics of his or her choosing, making it a truly parametric tool.

6.0 Recommendations

Though the accompanying tutorial and dynamic models were designed following the established guidelines for the creation of instructional media, they have yet to be tested. A series of evaluations are suggested, including gathering feedback from students with and without a formal technical background with respect to allotted time, clarity of explanation, and general format. Once the necessary audio equipment becomes available, the replacement of text with verbal narration would be a welcome improvement. The addition of increasingly complex models and probes for higher-ordered learning could also prove beneficial. Ideally, the tutorial would also be expanded to cover the force concepts covered in Dynamics of Machinery (ME3311).

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- Introduction Email -

I'm currently doing research in an effort to determine the effectiveness of multimedia resources as a supplement to the predominantly text-based machine design courses at WPI. As an IQP, I'll be developing a series of 3D dynamic computer simulations for use in ME 3310 and ME 3311. As a student who has completed one or both of these courses, your feedback will be invaluable in determining which topics would be best addressed in this manner as well as how they should be presented. Please take 10 - 15 minutes to complete this brief questionnaire. All responses will be kept strictly confidential and be viewed by me alone. If you would prefer to complete the survey online, [click here](#). In addition, if you would be willing to participate in an interview over lunch (my treat), please let me know. Thank you in advance for your help.

Questionnaire for ME3310 and ME3311

In which term did you take ME3310 Kinematics?

- A02
 C03
 Other

Please indicate the average number of hours you dedicated to related coursework each week:

ME3310:

- 0-5
 6-10
 11-20
 21-30
 Over 30

In which term did you take ME3311 Dynamics of Machinery?

- Did not take
 B02
 Other

Please indicate the average number of hours you dedicated to related coursework each week:

ME3311 (skip this question if you have not taken ME3311):

- 0-5
 6-10
 11-20
 21-30
 Over 30

The following is a partial list of the topics discussed in ME 3310. First rate the level of difficulty associated with learning each concept, and then rate how well you understand each one today. Please use the following scales.

Difficulty: 1=Very Easy 2=Easy 3=Average Difficulty 4=Moderately Difficult 5=Extremely Difficult

Understanding: 1=Don't Understand 2=Some Understanding 3=Average Understanding 4=Good Understanding 5=Understand Completely

Kinematics of Mechanisms										
	Difficulty					Understanding				
	1	2	3	4	5	1	2	3	4	5
1. Spatial relations of moving parts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Coupler Curves	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Dwells	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Straight-Line Linkages	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Quick-Return Mechanisms	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Slider-Crank Mechanisms	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. Instant Centers of Velocity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. Centroides	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. Mechanical Advantage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. Velocity of Slip and Transmission	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. Toggles	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. Relative Velocity of Points on Links (magnitude and direction)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. Acceleration of Points on Links (magnitude and direction)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The following is a partial list of the topics discussed in ME 3311. Please skip this section if you did not take ME3311. Otherwise, please rate the level of difficulty associated with learning each concept, and then rate how well you understand each one today. Please use the following scales.

Difficulty: 1=Very Easy 2=Easy 3=Average Difficulty 4=Moderately Difficult 5=Extremely Difficult
Understanding: 1=Don't Understand 2=Some Understanding 3=Average Understanding 4=Good Understanding 5=Understand Completely

Dynamics of Machinery										
	Difficulty					Understanding				
	1	2	3	4	5	1	2	3	4	5
21. Bearing Forces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. Dynamic Behavior of Fourbar Linkages	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. Linkage Balancing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. Input Torques	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. Effects Caused by Flywheels	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
26. Inertial Forces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
27. Static Engine Balancing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
28. Dynamic Engine Balancing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

In your opinion, which of the previously listed concepts could be demonstrated using dynamic 3D

computer simulations? (Check all that apply)

Kinematics of Mechanisms		Dynamics of Machinery
<input type="checkbox"/> 1. Spatial relations of moving parts	<input type="checkbox"/> 8. Centroides	<input type="checkbox"/> 21. Bearing Forces
<input type="checkbox"/> 2. Coupler Curves	<input type="checkbox"/> 9. Mechanical Advantage	<input type="checkbox"/> 22. Dynamic Behavior of Fourbar Linkages
<input type="checkbox"/> 3. Dwells	<input type="checkbox"/> 10. Velocity of Slip and Transmission	<input type="checkbox"/> 23. Linkage Balancing
<input type="checkbox"/> 4. Straight-line Linkages	<input type="checkbox"/> 11. Toggles	<input type="checkbox"/> 24. Input Torques
<input type="checkbox"/> 5. Quick Return Mechanisms	<input type="checkbox"/> 12. Relative Velocites of Points on Links	<input type="checkbox"/> 25. Effects Caused by Flywheels
<input type="checkbox"/> 6. Slider-Crank Mechanisms	<input type="checkbox"/> 13. Acceleration of Points on Links	<input type="checkbox"/> 26. Intertial Forces
<input type="checkbox"/> 7. Instant Centers of Velocity		<input type="checkbox"/> 27. Static Engine Balancing
		<input type="checkbox"/> 28. Dynamic Engine Balancing

How many of your previous classes have used multimedia resources to supplement traditional lecture and text-based materials (number of courses)?

- 0
- 1-2
- 3-4
- 5-6
- 7+

Please give an example of multimedia material that you found to be particularly useful during your studies at WPI.

How frequently did you make use of multimedia resouces that were not part of a formal assignment?

- Never
- Rarely
- Sometimes

- Often
- Always

Please rate your familiarity with the dynamic behavior of internal combustion engines:

- No Knowledge
- Some Knowledge
- Average
- Good Understanding
- Excellent Understanding

Have you ever watched the inner working of an internal combustion engine? Yes No
If yes, in what context (manuals, video animation, physical models, etc.)?

Have you ever disassembled an engine or any related components? Yes No
If yes, briefly describe your experience(s).

Have you ever repaired or modified an engine or any related components? Yes No
If yes, briefly describe your experience(s).

How do you rate your practical mechanical experience compared with that of your classmates?

- Significantly Less
- Somewhat Less
- About the Same
- Somewhat More
- Significantly More

How do you feel your previous mechanical experience (or lack thereof) affected your performance in ME3310? in ME3311?

What are your thoughts on the use of multimedia learning tools for use in machine design courses? What types would be most useful? How should they be integrated into the course? Please include any other general comments you have with regards to multimedia use in the classroom, the machine design courses offered at WPI, and this survey.

Please click on the button below to submit your survey.

ME3310 and ME3311 Questionnaire

Your survey has been successfully submitted. Thank you for your participation. This information will be invaluable in developing the foundation of this IQP. If you would like to receive a copy of the results of this survey, please email your request to peterman@wpi.edu.

WPI