

Humanizing Physics Project Final Evaluation Report

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Introduction

This report is the third annual internal report on the Humanizing Physics Project, and is the final and last report. Its purpose is to inform the project co-Principal Investigators and staff about the results of the evaluation data that have been collected and analyzed, and to provide information for any external reporting to the funding sponsor, the National Science Foundation.

The primary audiences for this report are the Principal Investigators (PI's) and project staff of the Humanizing Physics Project (HPP):

- Dr. Robert Fuller and Vicki Plano Clark, UNL
- Dr. Chris Wentworth and Dr. Mark Plano Clark, Doane College
- Dr. Nancy Beverly, Mercy College
- Dr. Beth Ann Thacker, Texas Tech University

This report summarizes the data from the evaluation instruments used with students involved in the project. In addition, some summative results on the project as a whole, from data gathered through observations and interactions with the co-Principal Investigators, is discussed.

Focus of the evaluation report

This evaluation focuses primarily on the evaluation data gathered from students, both attitudinal and achievement data. In addition, the instructors involved in the project were asked to reflect on their experiences in the project, and some of the information presented here summarizes their comments. The questions guiding this evaluation are:

1. How have students' learning and attitudes been impacted by participating in classes with Humanizing Physics units?
2. What have been some observed effects of the Humanizing Physics Project on the involved faculty and institutions?

Overview of evaluation plans and procedures

Instruments: At the start of the project, the Maryland Physics Expectations (MPEX) Survey (Redish, Saul, and Steinberg, 1998) was selected because it was a published attitudinal instrument in physics education that would provide the Humanized Physics Project with data about attitudinal change in students. Specifically, many of the concept clusters measured provided a general fit with the overall goals of the project: making physics more coherent to students, linking physics to the real world, representing physics through mathematical modeling, and having students recognize the extent to which their own efforts contributed to their understanding of physics. To address HPP goals not already included in the MPEX, an additional set of nine questions were added that focused more on the relevance of physics to students' future careers and to understanding medicine. This "Modified MPEX" instrument was then administered to students as a pre and post measure at all the HPP campuses. See the Appendix A for a complete copy of this instrument.

The Force and Motion Conceptual Evaluation (FMCE) was used as the achievement measure. While limited to questions about force and motion, which is only a portion of the curriculum, this instrument is recognized and used by physics education researchers to assess learning and thus provides a somewhat standardized way to measure student learning of these concepts (see Thornton & Sokoloff, 1998).

Unfortunately, as the project progressed and neared the end of its funding period, fewer of the co-PI's participated in these evaluation efforts. While it was recognized that the MPEX and FMCE were not ideal instruments to measure progress and change in this project, the diverse instructional directions taken by the different co-PI's on the project and the limited resources for the evaluation made the development and validation of alternative measures challenging. A couple of the co-PI's did work to develop another type of instrument, which they called a "relevancy" measure. This survey attempted to assess student knowledge by asking students to rate how relevant the physics of electricity and the physics of optics were to a variety of phenomena, such as "hearing a live rock concert" and "the occurrence of a rainbow in the sky." This instrument showed some promise in assessing students in an alternative way that was more closely aligned with the project methods and goals. However, issues with interpretation and item validity make it difficult to understand what was being measured. Nonetheless, results from this measure are presented with caution.

Other measures of student opinions and attitudes about the courses and the Humanized Laboratory Exercises or Units were administered at the different participating sites and results of any analyzes conducted on these measures are included where feasible.

Finally, because this was the third and final year of the project, the co-PI's were all asked to respond via email to two questions about their experience with the project. The first asked them to reflect on what HPP helped them gain or accomplish which they would not otherwise have been able to do. This question was posed because in evaluating the worth or utility of the project as a whole, understanding the value of the funding in bringing about change is critical. The second wrap-up question was about the utility of the evaluation. This question was included because the evaluation efforts appeared to reflect much about the project as a whole. The difficulty in coordinating, organizing, gathering, and reporting evaluation data seemed to mirror some of the difficulties in the organization and collaboration in the project as a whole. It was hoped that having the co-PI's reflect on this aspect would help make sense of the project overall.

Report Format: Similar to the Year 2 HPP Evaluation Report, this report is organized by institution. The efforts of each site will be briefly summarized and the data collection will be described. Then, the results of the data analysis will be presented. At the end of the report, a discussion of the overall evaluation conclusions will be detailed.

Interpretation of MPEX results: The MPEX was designed to measure students' attitudes and understanding about physics through a set of items that are rated by the students. These items were validated through an administration to physics "experts," professors and graduate students with an advanced comprehension of physics content. Students' scores on the MPEX are calculated by assessing the percentage agreement (favorable) and percentage disagreement (unfavorable) with these experts. The clusters items are described here to illustrate the results that follow.

The first cluster (represented by items 1,8,13,14,17, & 27) is the “independence cluster.” This cluster was designed to ascertain whether students tend to view knowledge as something that the instructor provides to them or whether they have a more constructivist perspective. The expert group agreed with the constructivist perspective and felt that students should disagree with items such as

#1: All I need to do to understand most of the basic ideas in this course is just read the text, work most of the problems, and/or pay close attention in class.

The second cluster (items 12, 15, 16, 21, & 29) is the “coherence cluster.” Physics faculty generally agreed that students “should see physics as a coherent, consistent structure.” Students who see science as a collection of facts lack the understanding of physics as a coherent system, governed by a few simple laws and principles that describe many complex phenomena.

The third cluster (items 4, 19, 26, 27, & 32), called the “concepts cluster,” focuses on whether students view physics as simply applying an equation to a problem, or if they are aware of how physics concepts apply to more complex problem solving. Less sophisticated students tend to agree with item

#4 “Problem solving in physics basically means matching problems with facts or equations and then substituting values to get a number.

The fourth cluster (items 10, 18, 22, & 25), called the “reality link,” is a particularly important one for this project. Items in this scale are designed to ascertain whether students feel that their personal real world experience is relevant to their physics course and vice versa.

The fifth cluster (items 2, 6, 8, 16, & 20), called the “math link,” is designed to measure the extent to which students understand and recognize the important role of mathematical reasoning and modeling to describe and make predictions about physical systems.

The sixth and last cluster (items 3, 6, 7, 24, & 31) from the MPEX is called the “effort cluster.” How students approach studying, whether they can learn from their mistakes, and the extent to which they take the necessary steps to be successful in the physics course form the basis of this scale.

The last cluster (items 35-43) of the “Modified MPEX” is of our own making, called the “relevance cluster.” The items used here were primarily devised to measure the extent to which students see the physics course as relevant to their future careers in medicine and the utility of the information they are learning. While we have no “expert” ratings on this, we assumed the items that indicated that the physics was relevant as being favorable, and the items that indicated that the physics was irrelevant as being unfavorable.

Interpretation of Relevancy Questionnaire Results: The “Relevancy Questionnaire” was designed by two of the instructors involved in the Humanizing Physics Project in an effort to measure the extent to which students recognize and understand the relevance of physics to everyday occurrences. The 50 items on the Relevancy Questionnaire are everyday occurrences, such as “taking a digital photo,” “lifting a heavy box,” and “having static cling in the clothes found in a dryer.” Students were asked to rate how relevant the physics of electricity is to these

phenomena. They are then asked to rate the same items on how relevant the physics of optics is to these phenomena. Items were rated on a scale of one to five:

- 1=not at all relevant,
- 2=barely relevant,
- 3=somewhat relevant,
- 4=relevant,
- 5=very relevant.

To gauge student responses, it was necessary to first understand how physics instructors, in particular the co-PI's in the project, viewed these phenomena. Of the three co-PI's and senior staff who chose to rate the phenomena, agreement on the level of relevance was relatively low. Absolute agreement, with three instructors rating an item identically occurred with only 13 of the 50 items. Consequently, trying to assess student responses by degree of absolute agreement with instructors was deemed inappropriate. Therefore, student responses needed to be analyzed by level of agreement with items falling to one or the other extreme on the scale. Defining "agreement" as all three instructors rating an item with either 4 or 5 or rating an item with either a 1 or 2, 22 items emerged as viable. Ten of these were rated as relevant or very relevant to the physics of electricity or optics and twelve were rated as not at all relevant or barely relevant to the physics of electricity or optics.

It should be noted that one co-PI did not rate these items because she felt that what was being asked for was too unclear. She found the instrument items difficult to rate because "physics of electricity" can be thought of very specifically as about moving charges or more broadly about any phenomena involving electric and magnetic fields. As she began to rate them, she found herself answering "very relevant" to everything that needed to be plugged in, and not relevant to things that involved electrostatics or electric or magnetic radiation. In addition, she didn't want items included that were relevant, but not specifically taught in her class. These criticisms point out some of the issues that students also faced when rating these items. However, given the level of agreement by the small group of physics instructors who did rate these items, analyses of student responses were conducted in hopes of uncovering some changes from pre to post semester.

These items were analyzed first by applying the Rasch model to rank order the items by how well each item measured a student's overall ratings. In other words, this model is used to identify and rate how "difficult" or "easy" the items are, assuming that an instrument will have a range of items. The relevancy of physics to some statements will be consistently "easy" for most students to answer like the experts (co-PI's), while other statements are less obvious and more difficult to get "correct" or to agree with experts. Analysis of multiple classes revealed no consistent patterns with the items, indicating that the items as a set were not consistent in their difficulty level with respect to one another, even though the level of difficulty range was relatively great. This suggests that the measure may not be a good predictor of the construct that is being assessed. Given this, the Rasch model analyses was abandoned, and more traditional approach to the survey format analyses was conducted.

The items were grouped together as a scale and responses tabulated. Each student had a sum score for items that were deemed "relevant" by the instructors and a sum score for items that were deemed "irrelevant" by the instructors. Pretest and posttest scores were calculated and a t-test was conducted to determine level of significant change. Appendix B lists the items that were included in this final scale and the direction of the instructor ratings (relevant/not relevant).

Results

UNL

What have they done:

During the course of the HPP project UNL modified the lab activities that accompany the algebra-based physics course. While other elements of instructional change were initially also incorporated, the enduring, institutionalized change brought about by the Humanized Physics Project were the lab activities, in which all major topics were revised to include humanized content. The following revised units are now in use at UNL and are posted at the HPP website (<http://www.doane.edu/hpp/>):

[*Human Senses and Interactions In Nature*](#)
[*Biomechanics and Modeling Human Motion*](#)
[*Modeling the Circulatory and Respiratory Systems*](#)
[*Energy Regulation*](#)
[*Modeling Human Speech and Hearing*](#)
[*Bioelectromagnetism*](#)
[*Modeling Human Vision*](#)
[*Physics of Imaging the Human Body*](#)

What data we gathered:

During the final phase of the project, MPEX data continued to be collected in the two semester algebra-based physics course (PHYS 141 and PHYS 142) which parallels the humanized labs. In addition, some lab questionnaires were completed that asked for more qualitative and detailed input about the lab exercises. Finally, some classes of students were also asked to complete the “Relevancy Questionnaire” both pre and post course.

What we learned:

MPEX results: Overall, the results on the MPEX questionnaires remained consistent with the previous findings. In general, students’ attitudes towards physics became less favorable as they progressed from the beginning to the end of the semester, in both the first semester and second semester courses. However, there was some variation from group to group. These analyses were conducted on the following groups of students:

Spring 2003: Phys 141 (n = 74) and Phys 142 (n = 58)

Fall 2003: Phys 141 (n=64)

Spring 2004: Phys 141 (n = 75) and Phys 142 (n= 103)

Overall initial favorable ratings across the whole instrument ranged from 41% to 47% across the five courses reported here. Unfavorable ratings ranged from 26% to 31%. At the completion of the semester, favorable ratings ranged from 36% to 46%, unfavorable from 33% to 40%, indicating the generally students attitudes towards physics became less compatible with experts’ views of physics.

With respect to the specific clusters, there was little change in the clusters of “independence,” and “coherence.” The “concepts” and “reality link” clusters showed change in a few classes. The “math” cluster, the “effort” cluster, and the “relevance” cluster all had significant change in some classes from pre to post semester toward less agreement with experts.

MPEX Cluster results: Across all classes, there was little change in the “independence” cluster, suggesting that few students changed their view on the constructivist nature of learning physics. About one-third of students, at both pre and post-test, agree with experts on how to best learn physics.

The “coherence” cluster similarly saw little change from pre to post semester. There tended to be higher levels of agreement with experts, with nearly 50% of students at pre and post-test agreeing with experts. Again, this indicates that students’ views about seeing physics as a coherent, consistent structure changed little.

There were a few significant changes noted in the “concepts” cluster on the MPEX. While the favorable percentages remained unchanged at about 38%, the unfavorable ratings rose slightly, with significant changes were observed in two of the classes (PHYS142 Spring 2003 and PHYS141 Spring 2004). In both of these classes, the unfavorable rating rose by more than 10 percentage points, indicating that a significant number of students were more likely to disagree with physics experts and agree with statements indicating that physics is about finding the right equation for the problem rather than thinking about the underlying concepts.

The “reality link” cluster also showed some significant changes toward less favorable ratings. This cluster, along with the “effort” cluster, tended to see higher levels of agreement with experts than the other clusters, with 57% average favorable ratings at the pretest. This dropped slightly at the post test, while unfavorable ratings rose somewhat, indicating that some students were more likely to endorse items such as “*Physical laws have little relation to what I experience in the real world.*”

On average, just over one-third of students had favorable ratings in the “math link” cluster pretest, and this dropped somewhat by posttest. Unfavorable ratings moved from 28% pretest to 40% posttest, indicating that students were less likely to agree that mathematical reasoning and modeling had an important role in describing and making predication about physical systems.

A similar pattern occurred on the “effort” cluster, with 55% favorable rating on pretest dropping to 44% favorable rating on posttest. The unfavorable ratings rose from 19% pretest to 34% posttest. This “effort” cluster measured students’ approach to studying and efforts to be a successful student of physics. However, these items are geared rather strongly toward test preparation rather than lab work, and may not reflect on the efforts of this project.

Finally, the “relevance” cluster, which was designed specifically for the HPP project, also showed significant decline from pre to post test. While three of the classes (PHYS 141 Spring ‘03 and Fall ‘03, and PHYS 142 Spring ‘04) had little change from pre to post test, and even some slight positive changes, the remaining two classes both showed significant declines in favorable ratings. There was high variability across classes in these ratings with pretest favorable ratings ranging from 33% to 57% and pretest unfavorable ratings ranging from 13% to 38%. This likely reflects a disparity in students’ understanding about the class and its utility prior to taking the course. Students in the first semester (PHYS141) class tended to begin this class with lower favorable ratings than second semester (PHYS142) students. However, one PHYS142 class maintained high favorable ratings through the end of the semester while the other dropped 19%, a significant change.

Across all the PHYS 141 and PHYS142 classes, the MPEX results suggest that generally, most students do not change their attitudes about physics from the beginning of the course to the end of the course. However, a small portion of the students consistently move from a neutral position to a more negative stance by the end of the course in the areas of seeing the connections

between the real world and physics, in understanding the role of mathematics in physics, and in recognizing the relevance of the physics course to their own futures.

Qualitative Responses: In Spring 2004, first semester students (PHYS 141) were asked to provide brief written comments about the laboratory exercises. They were asked to “give an example of an activity that you did in this semester in lab that you felt was relevant for your future career goals.” Students (n=99) gave diverse answers, listing a variety of lab topics and examples, as well as more general skills, such as working on the computer. Some students wrote “none” or listed nothing. Table 1. below summarizes students’ responses. The units on the circulatory system and on the muscles and energy regulation were cited most frequently as relevant to students’ future careers.

Table 1. Percent of PHYS141 students citing different lab activities as relevant to their future career. (N=99, some students listed multiple activities)

Activity described	How described (examples)	Percent of students
Biomechanics and modeling human motion	“Spring expansion and its relationship to bones” “The lab on muscle movements” “Model walking, jumping, rotating arms and legs, muscle strength” “A lot of the labs had to deal with movement of body parts, which will help” “Looking at the physics of muscles”	30%
Modeling the Circulatory and Respiratory Systems	“The water flow activity was good.” “When we modeled the circulatory system” “I’m going to be a physician, so the blood lab is fairly relevant” “The cardiac flow lab”	23%
Energy Regulation	“Are you hot stuff” “The last lab on temperature”	5%
Modeling Human Speech and Hearing	“the lab with the sound intensity – ‘speak up’”	2%
All or many activities	“All of the times we were able to relate the principles to the body and how it works.” “Any health-related applications” “When we focused on the body” “Biology-related topics” “The biological/physiological aspects relate to my plan of going to medical school”	11%
Specific skills	“The computer use on all labs” “Graphing various velocity, position, and acceleration functions” “Using excel throughout the semester”	4%
None	“None,” “Nothing”	15%
No answer		9%

Students in the second semester course were also asked to identify the lab activities that were most relevant to their future careers. The three main units (Bioelectromagnetism, Modeling Human Vision, and the Physics of Imaging the Human Body) were all cited by numerous students, and many students specifically noted the medical or human aspects as being important, citing their plans to go into a health-related field. Table 2. summarizes the student responses.

Table 2. Percent of PHYS142 students citing different lab activities as relevant to their future career. (N=155, some students listed multiple activities)

Activity described	How described (examples)	Percent of students
Bioelectromagnetism	“The electrocardiogram part with the heart and dealing with the electrical aspect of body.” “How a circuit works.” “The neural electricity stuff was interesting to me” “EKG lab” “bio-electronics – measuring electrical properties of the body” “Working with magnetic fields”	25%
Modeling Human Vision	“Read a spectrometer” “Looking at lenses to correct near or farsightedness” “The eye lab – I could see now physics were related to a real, physical concept” “The optics stuff was great”	30%
Physics of Imaging the Human Body	“The osteoporosis lab” “Radiation labs were relevant as I’m going to be a dentist” “Producing images using radiation” “Looking and interpreting X-rays and also wavelengths and frequencies of them because I’m going to be a dentist” “X-ray activities”	39%
General skills	“The problem solving skills used and applying equations and principles to real life situation is relevant” “Anything that dealt with researching something”	5%
None	“None” “Since the labs were mostly medically based, nothing. Not everyone in here is going to med school!”	4%
All human based labs	“Anything having to do with body – like eye experiment and heartbeats”	2%
No answer		2%

With respect to the Relevancy Questionnaire, pre and post data were matched by semester, but not by student. Not all classes of students were administered this questionnaire, so the comparisons made were the following:

Fall 2003: Pre-Physics 142 with post-Physics 142

Spring 2004: Pre-Physics 141 with post-Physics 142.

Interestingly, both analyses produced the same significant result (see Table 3). Students were significantly more likely to agree with physics instructors at the end of the semester on the items for which the physics of optics or the physics of electricity was identified as *not relevant*. They were not, however, more likely to agree with physics instructors on the items for which physics was identified as *relevant*. In other words, students were better able to identify phenomena where physics was irrelevant but no better able to identify phenomena where physics was relevant. This mixed result does show measurable progress on the part of students' perceptions about everyday phenomena and its relationship to physics. Nonetheless, given the known properties of this instrument, further testing, refinement and analyses on this instrument is recommended before further use of it.

Table 3. Relevancy questionnaire: Mean number of items per student in agreement with faculty ratings.

Semester	Faculty rating	Pre-Semester			Post-Semester			t	p
		N	Mean	SD	N	Mean	SD		
Spring 2003	Relevant Items	112	8.3	1.8	117	8.9	1.9	-1.15	.25
	Irrelevant Items	108	9.4	2.9	110	10.2	2.4	-2.05	<.05*
Fall 2003	Relevant Items	79	8.1	2.3	62	8.5	1.8	-.52	.61
	Irrelevant Items	63	8.5	3.3	55	9.7	3.0	-2.25	<.05*

*statistically significant

Texas Tech

What they have done:

Dr. Beth Ann Thacker is now teaching a two-semester course (1403-1404) that incorporates both the humanizing elements of the HPP goals and the rewriting of Workshop Physics for algebra based physics, "Workshop Physics with Health Science Applications." These revisions were supported by both the HPP funding and a second grant that supported the Workshop Physics rewrite from the calculus based course.

The revised curriculum includes several labs that incorporate humanized elements, particularly the Fluids unit that uses blood pressure and other biological examples, and the Sound unit. As with all the instructors involved in the project, Dr. Thacker included elements that were developed by the other co-PI's, but ultimately designed her own instructional units.

What data we gathered:

Difficulties with data collection and reporting resulted in no additional achievement or attitudinal data analyses in this last year of the project.

Doane College

What have they done:

Dr. Mark Plano Clark and Dr. Chris Wentworth teach a Workshop style physics course at Doane. Their two-semester course incorporates many “humanized” units, and appears to be the most fully integrated humanized course within the project. They continue to incorporate more humanized content each semester, as they review and edit their co-PI’s units as well as create and refine their own units. These include:

- Biomechanics and Modeling Human Motion
- Modeling the Circulatory and Respiratory Systems
- Energy Regulation
- Modeling Human Speech and Hearing
- Bioelectromagnetism
- Modeling Human Vision
- Physics of Imaging the Human Body

Their work on these units has included developing videos for the biomechanics unit, creating computer simulations that incorporate humanized animations, developing activities using rotary motion sensors, and developing laboratory apparatus to simulate blood flow and other human functions. The pedagogical style of their curriculum is now consistent across all activities, and almost all topics are introduced to students by a question about how the body works.

The digital videos they have produced are accessible to other faculty through the Doane College Physics Department Physics Video Library. As part of this project, they have also developed and maintained the HPP website, through which physics teachers around the world can access materials and information about humanized physics course content and resources.

What data we gathered:

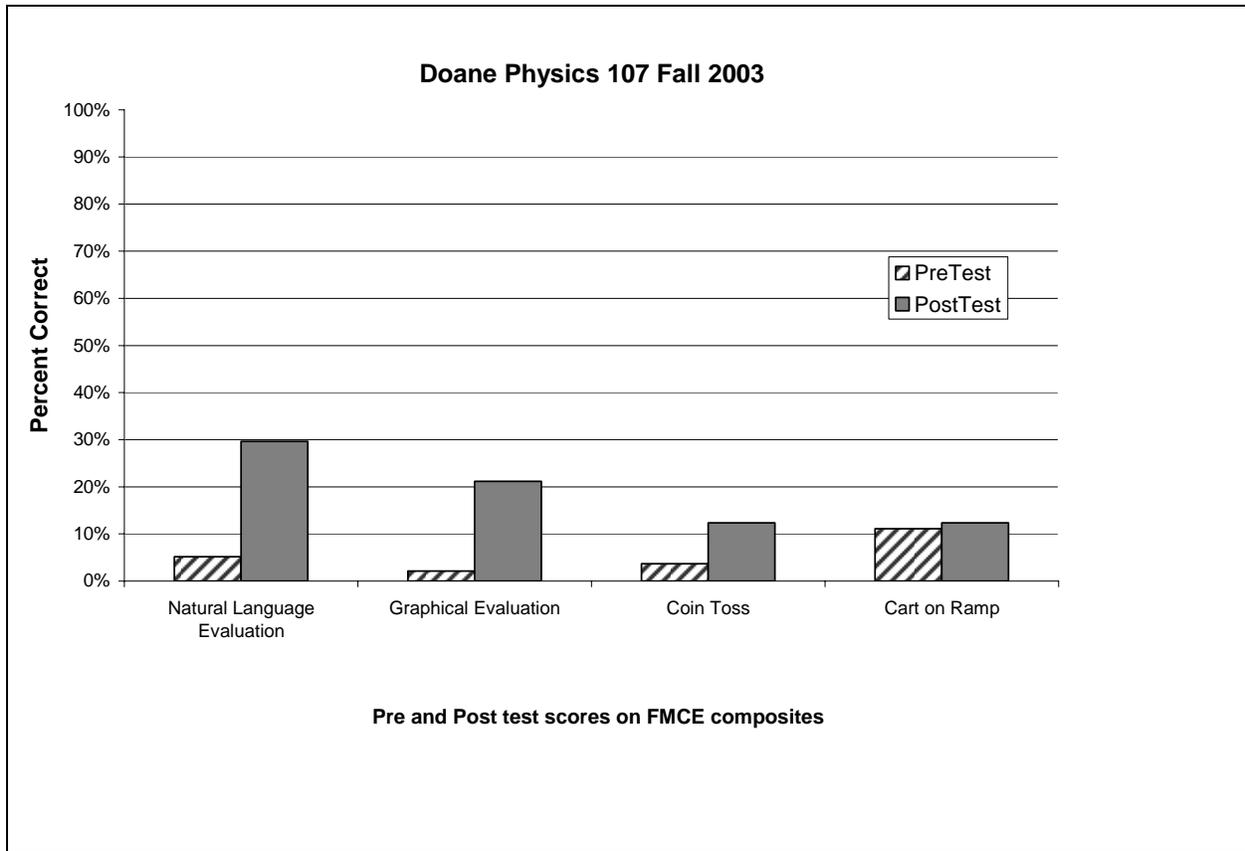
At Doane, both pre and post MPEX ratings were gathered each semester, and for Physics 107, the first semester course taught in Fall ‘03, FMCE pre and post scores were also obtained.

What we learned:

MPEX results: For Fall 2003, the Doane Physics 107 students showed decline in all areas of the MPEX scale. On every cluster, students rated their beliefs at the end of the semester as less like the physics experts than at the beginning of the semester. The most significant drops occurred in the “real” and “relevancy” clusters, suggesting that some students were less able at the conclusion of the course to see the connections between the real world and the physics they were learning and the relevance of the course to their futures.

For the Spring 2003 and Spring 2004, Physics 108 students, however, the patterns were different from 107 and similar to each other. Both of these courses had smaller enrollments, with complete data on only 7 (Spr2003) and 10 (Spr2004) students. Scores on several of the clusters either remained steady or declined somewhat, but ratings on the “independence” and “concepts” clusters went up in both groups, suggesting that some students were more likely to agree with a constructivist perspective on learning physics and were better able to see how physics applies to more complex problem-solving.

Achievement: As Figure 1. shows (below), post-test scores on the FMCE showed improvement from pre to post-assessment.



Qualitative comments: When asked to provide examples of what made an activity unit more interesting, students' responses fell into two primary categories. Two-thirds of the students felt that having hands-on experience made the activities more interesting, with comments such as,

When you can physically see results, as with human vision (for example with lenses,) it stimulates interest more than simply thinking about a concept (such as velocity of sound in blood).

Actually performing the experiments is a great learning tool.

One-third of the students felt that it was the application to the human body or practical life that made the labs more interesting.

If it relates to things about my body or what I want to go into.

When you can actually relate it to everyday things we use.

Mercy College

What they have done:

Dr. Nancy Beverly was the co-PI instructing at Mercy College in New York. She has incorporated many human applications in her workshop style physics courses, and with her release time from this grant, Dr. Beverly enhanced and expanded the humanized aspects of her courses. She has shared some of her developed units with the other co-PI's and has worked to modify others' units to use in her own classroom. As the supervisor of five adjunct physics instructors, she has worked to encourage and help these instructors use the Humanized Physics materials. In spite of her direct efforts, however, Dr. Beverly expressed disappointment in how much resistance these instructors showed and the difficulty they experienced using the materials. She felt that they were uncomfortable with the format, the computer aspect, the biological applications or the constructivist nature of the activities, and simply weren't able to effectively use the humanized units. Nonetheless, she has used and continues to modify her own course materials with her own classes and constantly adds new elements. She has found that adapting the other co-PI's units has been time-consuming because of the differences in sequencing, class contact time, and format. The difficulties that Dr. Beverly has encountered demonstrate some of the issues with which the project as a whole has had to contend. While interesting, workable, humanized units have been developed, the transferability of these units, and the effective dissemination of these ideas, methods and materials remains challenging.

What data we gathered:

Due to the extremely small classes and difficulties in working with the adjunct instructors with these humanized materials, no further achievement or attitude assessments were reported.

Long-term impact of Humanizing Physics Project

Goals of the HPP project included the institutionalization of humanized content in the algebra-based physics courses taught at the collaborating colleges and universities, the creation of a set of units that would be available and accessible to other interested faculty for their use, and recognition of their work in the physics education community, demonstrated by increased interest and understanding of the importance of humanized content in physics courses. In terms of long-term goals and accomplishments, this project has made an impact on the participants and institutions in a number of ways.

Co-PI's and senior staff review of accomplishments:

When the co-PI's and senior staff on this project were asked to reflect on the project and consider the impact of this project for themselves, most were reflective and specific in listing a variety of accomplishments that this grant enabled them to achieve. Both in terms of concrete resources, activities, and products as well as more intangible benefits such as experience, connections and personal growth, all but one co-PI cited how the project had created a lasting impact for the faculty and institutions involved in it.

- *Collaboration among professionals:* First and foremost, this project enabled a group of physics instructors to work together to share ideas, materials, and experiences in a significant and useful way. Almost every co-PI mentioned this aspect of the grant and its importance. Both among the project co-PI's and with others outside the project, these connections fostered greater creativity, follow-through, and productivity than would have been achieved if these individuals

worked in isolation. The senior PI on this project was able to bring together younger faculty to collaborate in a way that would have been difficult if not impossible without his leadership.

This collaboration was also instructive because it made the co-PI's not only more aware of the benefits of sharing ideas and resources, but also the inherent difficulties. Some of the PI's indicated that they would be more capable of and effective at collaborative work because of their experiences on this project.

- *Course materials and curriculum:* As a result of this project, every co-PI has a new set of curriculum materials and activities that are significantly different from their previous versions and that incorporate classroom-tested humanized activities. Some faculty continue to make significant modifications each year. Graduate and undergraduate student help, additional laboratory equipment, and release time were essential grant supported resources that enabled them to complete this work. In addition, one co-PI mentioned the creation of an infrastructure base that will help he and his colleagues continue to develop materials in the future. Through the grant support they have created a basic machine shop to develop activity apparatus. They also now have a high speed video camera to continue to create digital video resources for classroom use and software to create web-based multimedia such as Flash animations.

- *Dissemination of ideas and contributions to the physics education community:* Through the work of the grant, the involved faculty experienced increased visibility in the physics education community by attending AAPT meetings, presenting at these meetings and workshops, and connecting with other interested faculty. The work of this project is available on the project website and a listserv continues the communication of the dialog started at the Humanized Physics workshops. Project co-PI's collaborated with others outside the grant to produce a multimedia CD "Understanding Human Motion," which was published for the 2004 Summer meeting of the AAPT. One co-PI spoke at length on the interest of others in the work of the Humanized Physics Project, and cited leaders in the field, including Priscilla Laws and Joe Redish, who are now incorporating these ideas in their own work.

- *Professional development:* Most of the PI's reflected on their own personal learning and growth, and professional development. This project gave them exposure to different teaching philosophies, visibility in the physics education community, and colleagues with whom to collaborate. This project coincided and contributed to co-PI's securing tenure at their institutions. As a result of this project, one co-PI was asked to participate in curriculum projects to review materials, and negotiated a contract to produce a CD of web-based interactive physics problems. Another co-PI has been contacted to collaborate on an algebra-based physics textbook with biomedical applications.

- *Student involvement:* This project also provided opportunities for students, and involved both graduate and undergraduate students in course design and development. One co-PI reported that because of the positive experience for students in the class, some are seriously considering teaching at a small college as a career choice.

- *Resource acquisition:* Through the grant funding, the co-PI's gained release time, access to students' time and a graphic artist to help with aspects of the curriculum development, and a variety of equipment, including sensors, skeletal parts, optics equipment, a spectroscopy, radiation equipment, a high speed video camera, software for creating web-based multimedia materials, and other apparatus. These all enhanced the development of the curriculum units and also helped ensure that development and modification of the units continues to take place.

This list of accomplishments was generated by the co-Pi's and senior staff themselves as they reflected on their work through the grant, and provides a look at the individual accomplishments. While the goal of a set of units, edited and available for dissemination was not attained, the individual co-PI's were successful in developing their own set of units for use at their own institutions, as well as making versions of the units available to other instructors through workshops and online. It appears that the difficulties in collaborating across such geographical distances, as well as issues with the structure, layout, and sequencing of the units to agree on a final form, were too great to overcome in the limited time available. Lack of time to work together in face-to-face meetings hampered the efforts of the individuals in this project from the beginning, and made true collaboration difficult. In addition, as the experiences of the co-PI's showed, transferability of college-level curriculum is a complex and difficult issue.

Some of these issues were echoed in the evaluation and reporting, as well. The co-PI's reported that the evaluation process and reports helped them to think more about what they were trying to accomplish, it provided them with information about their students and also informed them about what was happening with other co-PI's in the grant. However, the measures used did not appear to be adequately assessing what the instructors saw happening in their classes and with their students. In addition, the measures were not always consistently administered to students and reported back to the evaluator for analysis. More discussion and work on defining student affective and achievement goals, and articulating these concepts would have helped make the evaluation more effective.

Discussion

As with any educational reform project, identifying, defining and articulating what is attempting to be accomplished is a daunting task. What student impact is sought? How will we know when we get there? Do all the co-PI's agree on these goals? Both in terms of assessing attitudinal change in students as well as measuring cognitive gains, the evaluation instruments need to be closely aligned with these goals. While both the MPEX and FMCE were imperfect measures for this project, we anticipated that they would be adequate and would reflect the changes sought. Qualitative measures were also included to help provide a more detailed picture of student opinion and affective change. In fact, the quantitative measures (MPEX and FMCE) returned mostly disappointing results. MPEX pre to post scores, on the whole, generally failed to show the sought after changes and even showed changes in a negative direction. Gains on the FMCE, while positive, were modest. Qualitative responses, on the other hand, did show that students enjoyed and remembered the humanized content of the labs, and mostly felt that they were relevant to their futures. Students seemed to understand and appreciate the human-based applications to physics problems. In combination with the MPEX results, however, this suggests that perhaps students were unable to generalize their learning to recognize the role of physics in approaching and solving real-world problems outside the classroom laboratory.

Reflecting on the measures used and evaluation conducted, it would have been helpful to have devoted more time and effort defining and articulating the goals of the project with respect to student change. In addition, it would have been helpful to assess and map the level of implementation of the humanized aspects of the courses at the different institutions throughout the timeline of the project. Each institution and affiliated co-PI(s) were unique in the way that they integrated the humanized elements. The need to work through the technical and

pedagogical aspects of the curriculum development took precedence over the identification of common goals and a way to measure success with respect to student impact.

Overall, the student impact of the project appears mixed, and as different at each institution as the differences in implementation of the project at each institution. The humanized content appears promising and students do find it relevant and appealing. As instructors are able to better define what lasting effects they want to leave with their students as a result of these humanized physics courses, elements to achieve these effects can be incorporated and ways to measure them can be developed. The measures used here suggest that most students find the humanized content interesting and engaging. At UNL with the humanized labs, but traditional lecture and recitation, students experienced slight negative change in their attitudes about the relevance and meaningfulness of physics as a whole. At Doane, with the Workshop Physics course that integrated many humanized units, some positive attitude change was measured during the second semester course.

This project resulted in considerable professional development for the co-PI's, who collaborated to create a series of units that incorporate human-based applications for this algebra-based physics course. While a single set of published, humanized units that are readily accessible and transferable to interested instructors was not disseminated, many classroom-tested units are available and downloadable from the project website. Overall, the development of humanized units for algebra-based physics was accomplished, and work continues to move forward in this area.

References

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Student Expectations about Physics

Here are 43 statements that may or may not describe your beliefs about this course. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:

1: Strongly Disagree 2: Disagree 3: Neutral 4: Agree 5: Strongly Agree

Answer the questions by circling the number that best expresses your feeling. Work quickly. Don't over-elaborate the meaning of each statement. They are meant to be taken as straightforward and simple. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, circle 3. If an item combines two statements and you disagree with either one, choose 1 or 2.

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|---|-----------|
| 1. All I need to do to understand most of the basic ideas in this course is just read the text, work most of the problems, and/or pay close attention in class. | 1 2 3 4 5 |
| 2. All I learn from a derivation or proof of a formula is that the formula obtained is valid and that it is OK to use it in problems. | 1 2 3 4 5 |
| 3. I go over my class notes carefully to prepare for tests in this course. | 1 2 3 4 5 |
| 4. "Problem solving" in physics basically means matching problems with facts or equations and then substituting values to get a number. | 1 2 3 4 5 |
| 5. Learning physics made me change some of my ideas about how the physical world works. | 1 2 3 4 5 |
| 6. I spend a lot of time figuring out and understanding at least some of the derivations or proofs given either in class or in the text. | 1 2 3 4 5 |
| 7. I read the text in detail and work through many of the examples given there. | 1 2 3 4 5 |
| 8. In this course, I do not expect to understand equations in an intuitive sense; they must just be taken as givens. | 1 2 3 4 5 |
| 9. The best way for me to learn physics is by solving many problems rather than by carefully analyzing a few in detail. | 1 2 3 4 5 |
| 10. Physical laws have little relation to what I experience in the real world. | 1 2 3 4 5 |
| 11. A good understanding of physics is necessary for me to achieve my career goals. A good grade in this course is not enough. | 1 2 3 4 5 |

1: Strongly Disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree
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| 12. Knowledge in physics consists of many pieces of information each of which applies primarily to a specific situation. | 1 | 2 | 3 | 4 | 5 |
| 13. My grade in this course is primarily determined by how familiar I am with the material. Insight or creativity has little to do with it. | 1 | 2 | 3 | 4 | 5 |
| 14. Learning physics is a matter of acquiring knowledge that is specifically located in the laws, principles, and equations given in class and/or in the textbook. | 1 | 2 | 3 | 4 | 5 |
| 15. In doing a physics problem, if my calculation gives a result that differs significantly from what I expect, I'd have to trust the calculation. | 1 | 2 | 3 | 4 | 5 |
| 16. The derivations or proofs of equations in class or in the text has little to do with solving problems or with the skills I need to succeed in this course. | 1 | 2 | 3 | 4 | 5 |
| 17. Only very few specially qualified people are capable of really understanding physics. | 1 | 2 | 3 | 4 | 5 |
| 18. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed. | 1 | 2 | 3 | 4 | 5 |
| 19. The most crucial thing in solving a physics problem is finding the right equation to use. | 1 | 2 | 3 | 4 | 5 |
| 20. If I don't remember a particular equation needed for a problem in an exam there's nothing much I can do (legally!) to come up with it. | 1 | 2 | 3 | 4 | 5 |
| 21. If I came up with two different approaches to a problem and they gave different answers, I would not worry about it; I would just choose the answer that seemed most reasonable. (Assume the answer is not in the back of the book.) | 1 | 2 | 3 | 4 | 5 |
| 22. Physics is related to the real world and it sometimes helps to think about the connection, but it is rarely essential for what I have to do in this course. | 1 | 2 | 3 | 4 | 5 |
| 23. The main skill I get out of this course is learning how to solve physics problems. | 1 | 2 | 3 | 4 | 5 |
| 24. The results of an exam don't give me any useful guidance to improve my understanding of the course material. All the learning associated with an exam is in the studying I do before it takes place. | 1 | 2 | 3 | 4 | 5 |

1: Strongly Disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree
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25. Learning physics helps me understand situations in my everyday life. 1 2 3 4 5
26. When I solve most exam or homework problems, I explicitly think about the concepts that underlie the problem. 1 2 3 4 5
27. "Understanding" physics basically means being able to recall something you've read or been shown. 1 2 3 4 5
28. Spending a lot of time (half an hour or more) working on a problem is a waste of time. If I don't make progress quickly, I'd be better off asking someone who knows more than I do. 1 2 3 4 5
29. A significant problem in this course is being able to memorize all the information I need to know. 1 2 3 4 5
30. The main skill I get out of this course is to learn how to reason logically about the physical world. 1 2 3 4 5
31. I use the mistakes I make on homework and on exam problems as clues to what I need to do to understand the material better. 1 2 3 4 5
32. To be able to use an equation in a problem (particularly in a problem that I haven't seen before), I need to know more than what each term in the equation represents. 1 2 3 4 5
33. It is possible to pass this course (get a "C" or better) without understanding physics very well. 1 2 3 4 5
34. Learning physics requires that I substantially rethink, restructure, and reorganize the information that I am given in class and/or in the text. 1 2 3 4 5
35. I probably won't need physics after I finish with this class. 1 2 3 4 5
36. This physics class is just a hurdle to jump so I can move forward with my goals. 1 2 3 4 5
37. The things I learn in this class will be important in my future career. 1 2 3 4 5
38. It is necessary to understand physics to have a career in the health sciences. 1 2 3 4 5
39. A primary purpose of this class is to "weed out" some students and prevent them from pursuing a medical career. 1 2 3 4 5

1: Strongly Disagree	2: Disagree	3: Neutral	4: Agree	5: Strongly Agree
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40. Physics plays a key role in understanding modern medicine. 1 2 3 4 5
41. I'll probably never use the physics from this class again. 1 2 3 4 5
42. The physics taught in this class helps prepare students for a medical career. 1 2 3 4 5
43. The physics I am learning in this class is valuable for future reference. 1 2 3 4 5

Appendix B

Items from Relevancy Questionnaire used in final analysis (items for which experts agreed on relevancy or irrelevancy), and direction of expert rating.

Physics emphasizes the study of electrical concepts such as voltage, electric fields, current, and circuits. How relevant to you think the physics of electricity is to the following phenomena? Circle the number that corresponds to your answer for each category.

How relevant do you think the physics of electricity is to the following phenomena?
(1=not at all relevant, 2=barely relevant, 3=somewhat relevant, 4=relevant, 5=very relevant)

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|--|----------|
| 2. The sound system at a concert. | Relevant |
| 13. Shining a flashlight | Relevant |
| 17. Taking a digital photo | Relevant |
| 18. Measuring an EKG of a patient's heart. | Relevant |
| 23. Having static cling in the clothes found in a dryer. | Relevant |

Physics emphasizes the study of optical concepts such as refraction, reflection, image formation, and lenses. How relevant do you think the physics of optics is to the following phenomena? Circle the number that corresponds to your answer for each category.

How relevant do you think the physics of optics is to the following phenomena?
(1=not at all relevant, 2=barely relevant, 3=somewhat relevant, 4=relevant, 5=very relevant)

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|--|--------------|
| 28. Sensing the roughness of an object with your finger. | Not relevant |
| 31. Lifting a heavy box. | Not relevant |
| 32. Walking at a natural pace. | Not relevant |
| 33. Seeing a painting. | Relevant |
| 35. Breathing. | Not relevant |
| 36. Riding an elevator. | Not relevant |
| 37. Looking at your reflection in a mirror. | Relevant |
| 39. Being protected by an airbag in a car crash. | Not relevant |
| 40. Taking an x-ray image of a patient's teeth. | Relevant |
| 41. Running an air conditioner. | Not relevant |
| 42. Taking a digital photo. | Relevant |
| 45. Occurrence of a rainbow in the sky. | Relevant |
| 46. A textbook sitting on a table. | Not relevant |
| 47. Using a cane while walking. | Not relevant |
| 48. Having static cling in the clothes found in a dryer. | Not relevant |
| 49. Measuring a patient's blood pressure while sitting. | Not relevant |
| 50. Smelling the sea air at the beach. | Not relevant |