Physics Faculty Demographics and the Curriculum as a Reflection of Their Work

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1 Introduction

Originally, this documentation of physics faculty work roles was intended to look at how physics faculty develop and implement curricular reforms. However, there is very little research discussing physics faculty explicitly let alone their roles in curricular reform. To illustrate this fact, consider the major journal focusing on physics instruction, *The Physics Teacher*, which is published by the American Association of Physics Teachers. In a literature search through this journal, only one article dealt directly with physics faculty in the past 13 years! This leads to the preliminary result of this research, which, unfortunately, is a null one—due to the strict focus on hard physics research (i.e. research dealing directly with physical concepts), aspects of other faculty work is rarely documented. It is obvious, however, that faculty play the vital role in the curriculum since they are the gatekeepers of the discipline, develop the curricula and implement it as well.

With this in mind, one can look at the curriculum as a reflection of faculty work. However, even inferring these work roles from the curriculum is difficult since many papers concentrate on the cognitive psychology of the student rather than expounding on the methodology that faculty used to develop the curriculum. Another difficulty in discussing curricular reforms in physics is that the physics curriculum is relatively well established as far as content is concerned. Therefore most curricular reforms take the form of changes in the delivery of the material to the students.

This review is comprised of two parts—the first establishes the current numbers that characterize faculty demographics and the second introduces a short history of the physics curriculum and discusses reforms that have shaped the physics curricula today.

The literature for faculty demographics largely takes the form of statistical discussions of surveys that are mostly wide in scope (such as the AIP Reports). However, the few articles that discuss the environment of two- and four-year institution faculty are small in scope and dated but, in the scope they do cover, are statistically sound. The literature for the history of the curriculum and curriculum reform is narrative in nature with some small scale statistical evidence that one should be careful about taking at face value since most of these statistics were investigated by the curricular reformers and the results may not be objective.

In considering the following review and its primary null findings, consider the following quote by Art Hobson of the University of Arkansas in a letter to the editor of the American Physical Society's Forum on Education's August 1999 Newsletter on the state of faculty and lack of documentation on educational documentation:

> Essentially, every tenured member at the nation's nearly 200 Ph.D.-granting physics departments is a researcher. They would cut their own throat by taking on a K-12 project or any other educational project, because hiring, pay, promotions and tenure are all based nearly exclusively on research as measured by publication, grants, etc. Most of these departments are eager to hire and to tenure promising researchers, even if they have only minimal teaching skills. But most would not hire an outstanding teacher who does not have great promise in "pure physics" research, and would not grant such a person tenure despite evidence of significant creative work in course development, text materials, mentoring, K-12 outreach, etc. [1].

2 Faculty Demographics

To begin to form the picture on physics faculty work roles, one must first identify who comprises physics faculty. In this section the general demographic of faculty will be established (focused mostly on faculty in four-year institutions), such as degree level and minority components, followed by separate sections focusing specifically on concerns applicable to the two-year college and four-year institution, respectively.

2.1 *General*[1]

Nearly all physics faculty that are employed by four-year institutions have earned a Ph.D. [2], less than 10% of physics faculty employed by two-year institutions have earned a Ph.D. while, at minimum, 96% have earned at least a master's degree [3]. Degree granting physics departments (excluding associate degrees) in the United States employed about 8375 of full-time equivalent (FTE) physicists during the spring of 2000 [4].

There are three major underrepresented groups among physics faculty: African-American faculty, Hispanic faculty and female faculty. African-American faculty represent a mere 1.8% of all physics faculty in the year 2000 compared to 5% of faculty in all disciplines. Historically Black Colleges and Universities (HBCU's) employ two-thirds of the African-American physics faculty lowering the percent of African-American faculty at non-HBCU's to less than 1% [5]. Therefore, African-American faculty tend to concentrate in HBCU's. This concentration trend does not apply to the Hispanic faculty demographic—the

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[1] Unless explicitly noted, statistics noted here are dealing with four-year universities due to lack of data on two-year institutions. A general picture of two-year colleges will be address in the following section entitled "In the two-year institution."

distribution of Hispanic faculty among various types of departments (bachelor's, master's, doctoral) are similar to the distribution of all faculty in physics. Overall, 2% of all physics faculty are Hispanic [6]. As far as the female demographic is concerned, the proportion of women teaching physics decreases as academic rank and the level of department increases. However, the percentage of women faculty members at each rank is at least as high as the percentage of women earning Ph.D.'s at various points in the past [7]. In 1996, 11% of two-year college professors were woman and in 1998, 8% of college and university physics professors were women [8].

The retirement rate of physics faculty has risen from a high of 2.6% prior to 1999 to 3.3% in 2000 with turnover rates for the 1999 academic year of 7.3% (this includes retirements, resignations and deaths) [9]. With the decreasing production of physics Ph.D.'s (an 11% drop in earned physics Ph.D.'s has been observed from 1996 to 2000 [10]) and increasing retirement and turnover rates indicate that the physics faculty demographic has the possibility of increasing the numbers of younger faculty in the coming years. It is very uncommon, however, for the previous title of new faculty to be graduate student (i.e. for new faculty to be employed in academia directly after graduating with their Ph.D.) [11]. Most commonly, a new faculty member would have had previous positions of Post Doctorial Fellow, Research Scientist or a Visiting Professor at another institution.

2.2 In the Two-Year College

As noted previously, there has been very little attention paid to physics faculty employed at two-year colleges. In an article that appeared in 1995 in *The Physics Teacher*, Judith Tavel noted this same situation, "I discovered that, in general, there was very little data on TYC [two-year college] faculty and absolutely no data on TYC *physics* faculty" [12]. In order to help remedy the situation, she decided to put out a survey to define who two-year college physics faculty were and to gain some insight into their opinions on their current situation. The first survey was a general survey (dealing mainly with the number of physics faculty, the number of courses taught, the number of students served and the number of contact hours required) mailed to all 1527 institutions listed on the American Association of Community Colleges mailing list in 1989. Of that mailing, a total of 419 responses were received initially but by June of 1993 she had received replies from nearly two-thirds of institutions. The second survey (1993) was similar in nature but expanded the scope of its questions to refine the specifics of each area and allowed for free form responses from faculty in the hopes a gain greater depth and explanation of responses. Of the 1542 institutions the survey was mailed to, only 313 responded. This was most likely due to the increased length to 11 pages in the second survey from 1 page in the first. She summed the results of these surveys in the following:

> On the most general and superficial level, the following picture emerges. As indicated by the 1,013 schools responding to the first survey, 96% of the physics faculty have at least a master's degree, 8% have a Ph.D., and 28% have two master's degrees or some other significant course work or professional experience. The average contact-hour load is 19.2 hours per semester; the average number of students served by each faculty member is 150; the average number of course taught per semester is 2.5 physics courses with a laboratory, and 0.8 other courses [13].

One of her findings from this picture is that two-year college faculty are overworked. She recognized that serving 150 students is a moderate number of students to serve in a four-year university but also notes that the average two-year college faculty has very little support and is responsible for every aspect of their students' education. Also, with respect to faculty commenting on the number of students served and the clerical work involved in student evaluation, most faculty indicated it was the special needs of the wide variety of students that made the workload so exhausting.

So what is the motivation of two-year faculty members to undertake the onus of this workload? Tavel states that is the, “love of teaching and interest in students was usually couples with dislike, even hatred, of traditional physics research of the kind that is required at a four-year college or university” [14]. The two-year college faculty also generally feels that they are isolated from the rest of the physics community, looked down upon by faculty in four-year universities and that they often thought that two-year college teachers were their own worst enemies by not value themselves highly enough.

The faculty at two year colleges also employ many of the new pedagogies developed recently for introductory physics instruction even if they were not explicitly aware of the programs their new methods originated from. In regard to new introductory physics curricula Tavel stated:

> …I asked about knowledge of the Introductory University Physics Program (IUPP) and Workshop Physics… Even though the label IUPP was not as universally recognized, 82% of the responders listed at least one of the IUPP concepts: covering fewer topics in more depth (“less is more”), integrating the topics with a coherent theme or “storyline,” and emphasizing contemporary physics topics [15].

Both of these programs (the IUPP and Workshop Physics) will be discussed in more detail later in this discourse.

Tavel concluded her discussion with the following statement:

> The surveys clearly indicate that the ultimate role of the TYC in higher education will be shaped and directed by the nature of its faculty… These strengths, such as the focus on students, attention to introductory pedagogy, and they willingness to take students from where they are to where they need to go, make it possible for the two-year college to have a leadership role in introductory college education [16].

2.3 In the Four-Year University

Studies of physics faculty in four-year universities are also lacking, in general. The American Physical Society (APS) periodically conducts surveys on physics faculty the latest of which was published in *Physics Today* in 1991 [17]. It refers back to the closest previous study which took place 1977! The 1991 survey is also not all-inclusive in that it looks specifically at new faculty in 175 Ph.D. granting institutions in the United States.

The findings are summed up in the following:

> Our principle finding is that young physicists are experiencing serious difficulties in obtaining research support. For those who submitted proposals to launch their own research programs, only one proposal in three succeeded in attracting funding. Of the successful proposals, only two out of five were funded at the requested amount. When asked their view of the support situation, the majority of the young physics faculty characterize it as seriously inadequate [18].

When comparing young faculty's views on their current situation, both faculty from the 1977 survey and the current survey being discussed (1991) reported feeling that they felt that they has made the right career choice in pursuing physics but there was a striking difference in their attitude towards support; in 1977 two-thirds of the young physicists felt that support was adequate and today the same proportion say it is seriously inadequate.

The free responses of faculty members are telling:

> I'm doing fine; I know others that are not. I succeeded by (a) collaborating with others, thus getting credibility in areas where I had no track record and (b) emphasizing applied aspects. I don't regret doing either, but some cannot. Funding for basic research is an absolute disaster.
>
> I have seen the best minds of my generation driven from high-energy theory into mind-numbing jobs, their talents and training (and the public funds which helped pay for that training) gone to waste. How soon before I join them?
>
> Grant agencies put young researchers into a Catch-22 situation: They expect a track record, which comes from previous grant support, but for many it is difficult or impossible to get that initial grant! [19]

When young physics faculty begin their careers, their success is fundamentally affected by their initial success in obtaining funding. For the majority of young investigators (60%), this support came in the form of university startup funds. However, experimentalists are more likely than theorists to have received university startup support (65% of young experimentalists receive startup funds compared to 54% of theorists). Of those that were able to gain university startup funds, they were only supported, on average, with two-thirds of the funds needed to start their own research programs. Most other young faculty got started on a group grant or by working under an existing grant. Only 9% were first supported as principal investigators on their own grants, and most of the faculty in this group required four or more years to obtain their first support. About 7% of the young physics faculty had never received research support.

Besides university startup funds, the dominant external source of funding came from the National Science Foundation (NSF), being sited by 49% of respondents. The Department of Energy was the second largest source of external funding being sited by 23% of respondents. The Department of Defense and the NASA were also mentioned, sited by 14% and 13% of respondents, respectively. Other sources included Sloan Fellowships, the Petroleum Research Fund administered by the American Chemical Society and grants from local industries, typically for equipment.

Besides revealing the pessimistic outlook on funding among young faculty, the survey also established their demographics. As mentioned previously, most young faculty do not find their academic positions directly out of graduate school. Academic physicists usually begin their careers as post-doctorial researchers and once they enter the professorate they enter at the assistant professor level. After four to six years, those who survive in academia are often promoted to associate professor—the majority of those with nine or more years experience are associate or full professors.

The young faculty were also surveyed on their satisfaction with physics as a career choice and perceptions of career directions, the job market and the availability of funding. The following quote summarizes their responses:

> As a group, the young physicists say that their positions are professionally challenging, that their careers have gone pretty much in the direction they had intended and that they would recommend physics as a field for a bright young person. Few of the respondents say that if they had it to do it over again they would go into a different subfield of physics (11%) or an area other than physics (10%) [20].

As illustrated in the previous quotes from young faculty members, this positive outlook on the state of the physics professorate is not shared by everyone. In a response to the statement, “Research support for young faculty is generally adequate for establishing a research track record,” 69% of the young physics faculty disagrees with the statement, while only 11% agree. Since “establishing a track record” is synonymous with advancing professionally, such a response indicates a serious problem.

3 The Development of the Curriculum as the Reflection on Faculty Roles

With so little information relating directly physics faculty work roles, on can look at the physics curriculum as a reflection of their work. Since the physics curriculum is primarily a structure of the disciplines curriculum, examining the curriculum in order to consider the roles of its faculty is reasonable. After all, it is the faculty that define the discipline itself, design the curriculum to reflect the discipline and then implement it. And many of the great physicists were faculty members in higher education! With that in mind, consider the development of the physics curriculum over time.

3.1 A Brief History of the Physics Curriculum

The physics curriculum as we know it today originated in the liberal arts education of medieval universities. At this time, the curriculum consisted of two major components—the *trivium* which consisted of the study of grammar, rhetoric and dialectic, and the *quadrivium* which consisted of the study of geometry, astronomy, arithmetic and music. At this point in time, higher education was reserved for the elite sons land owners and not for the general public. Higher education served the purpose of educating these elite to be proper gentlemen and good citizens, hence the emphasis on general education.

At this point of time, physics was not a science as known today, but was more properly recognized as a natural philosophy. Physics concepts were often offsprings of though experiments and logic loosely coupled to observation. The physical reasoning of Aristotle remained the epitome of physical reasoning at the time. These pretenses included that the rate at which objects accelerated to the earth was dependent on its mass and that the universe was centered on the stationary earth. The political power of the Catholic Church over Europe also helped in sustaining the Aristotelian physical concepts since such pretenses as a geocentric universe reinforced religious dogma.

With revolutions in physics by Copernicus (1543) and Galileo (1632), the scientific method became firmly established and physics evolved from a natural philosophy into a science. With physics' new establishment as a science, Newton ushered in mechanics and gravitation. Later, Maxwell would usher establish the laws of electricity and magnetism.

As physics changed, so did its curriculum. By the end of the nineteenth century, physics incorporated into the undergraduate curriculum. The educational goals of higher education at this point in time was still focused on general education. The degree earned was often called applied science in a Bachelor of Science degree outside of the traditional Bachelor of Arts degree. This is not to imply that the required general education courses did not dominate the curriculum as a whole since both degrees still required only about one-third of the total course work in mathematics and sciences. It was presented almost solely in the traditional style, that is, that the instructor was the “full cup” and the student the “empty cup.” The instructor lectured and the students learned. There was very little student involvement or consideration of their learning styles. Educational experiences were centered on concrete experiences, laboratory work and recitation.

In the early twentieth century, the focus on general education shifted to the new major program and elective system that became popular in the United States. This also shifted the focus of the physics curriculum. Now, the curriculum was released from its main responsibility of making physics digestible by all students to focusing more on the details of the disciplines thus increasing the curriculum’s sophistication within the major program.

The World Wars brought an enormous amount content to all the sciences due to the focus on application of the sciences in the war efforts. This focus on application also filtered down to the curriculum and the wealth of new knowledge led to undergraduate instruction becoming more abstract and fragmented.

Once the space race was fully underway with the Russian launching of the first artificial earth satellite called *Sputnik*, America needed a strong scientific community and in order to promote its own space program. New attention was paid to the science curricula for student recruitment and retention. In this post-*Sputnik* era, there were several large-scale curriculum reform projects mostly supported by the National Science Foundation (NSF).

The reforms attempted to update the content of courses, make the processes of the discipline clear to the student in order to create more scientists. The curriculum tried to achieve these goals by placing emphasis on improving laboratory instruction, hands on learning and the discovery approach (which allowed students to investigate and internalize concepts for themselves). It should be recognized that the reforms where focused toward physics majors and not the general student population. After all, non-majors would not contribute to the space race effort.

After the landing a man on the moon in 1969, popular support for funding the space program dwindled. During this time, the supply and demand for physicists nearly balanced so there was little concern to increase the production of physics majors. Therefore, NSF funding for curricular reforms also declined drastically and ceased in the 1970’s and early 1980’s. Curricular innovation remained stagnant until the late 1980’s with some of the more modern reforms being implemented today [21].

4 Current Physics Curriculum Programs

4.1 Physics in the Secondary Curriculum

Many of the current reforms being done in the undergraduate physics curriculum originated in the secondary physics curriculum. There are many reasons for this including the fact that there is little research done, other than educational research at the secondary level, instructors at this level usually assume little to no prior knowledge of the students and that many secondary physics teacher dedicate much time to teaching seminars and are more likely to be risk takers since tenure is not an issue [22].

A common theme of both secondary and undergraduate physics curricular reform is addressing the following questions in order to internalize concepts in students:

- How do we know…?
- Why do we believe…?
- What is the evidence for…?

These questions make new concepts, insights, or lines of reason plausible, intelligible and comprehensible to students encountering them for the first time [23].

With this is mind it is worthwhile to examine some of the more significant secondary high school curricula.

4.1.1 PSSC (Physical Science Study Committee) Physics

Prior to 1956, the content and organization of physics at the high school level was highly influenced by the Harvard Descriptive List of Experiments, or by the periodic emphasis on the application of physics (toy physics, household physics, consumer physics, atomic age physics). In 1956, a conference was held at the Massachusetts Institute of Technology by Jerrold R. Zacharias, a professor of physics at MIT. The state of high school physics teaching was discussed and the seeds were planted for the development and implementation of a new course for physics in the high school which became known as PSSC Physics [24].

During the period 1956-1960, the PSSC (Physical Science Study Committee) Physics course was developed by several hundred physicists, high school teachers, apparatus designers, writers, and editors. The result was a course that contained a student textbook, teacher's guide, laboratory experiments, tests, films, and a series of paperback books on selected topics in science.

The PSSC Physics course departed from the traditional course in physics which emphasized facts and description of physics concepts; the PSSC course was designed to help students "do physics," by engaging the students in activities and thought processes of the physicist. The goals of this new program included helping students [25]:

- understand the place of science in society.
- understand physics as a human activity, and a product of human thought and imagination.
- appreciate the intellectual, aesthetic and historical background of physics.
- appreciate the limitations of knowledge about the physical world.
- understand that knowledge of physics comes about from observation and experimentation.
- appreciate the spirit of inquiry.
- appreciate the logical unity of physics and the way that physicists think about the world.
- understand basic principles of physics that manifest themselves in astronomical as well as human and atomic scales.

In the 60s and 70s there were a number of studies done by science educators to evaluate the effectiveness of PSSC Physics and the other course improvement projects, and also to compare their effectiveness to the traditional courses in the respective disciplines. Studies showed that PSSC students did better on higher-level cognitive tasks than their peers in traditional physics courses.

The PSSC course involved the students in a series of laboratory activities that were unique. Over fifty experiments were designed to support and help develop the concepts in the textbook. The experiments were not designed to verify a concept that had been introduced by the teacher or the textbook but, instead, the laboratory experiments created a novel situation in which students had to think about a problem, gather relevant data and analyze results [26]. In order to accomplish this, the PSSC developers designed special laboratory equipment that was simple, easily assembled and inexpensive. All other course improvement projects followed this pattern of designing special equipment [27] [28].

4.1.2 Project Physics

Another physics course developed during the period of PSSC Physics was Project Physics (originally, called Harvard Project Physics). It departed from the PSSC model, perhaps because the developers were science educators, and involved high school teachers from the beginning. Project Physics set out to develop a general education physics course based on good physics, but designed for citizens of the day.

Project Physics developed a course along humanistic lines, in that the developers were interested in emphasizing human values and meaning, as opposed to PSSC Physics, which focused more on the intrinsic structure of physics. Project Physics objectives were designed to help students understand and appreciate [29]:

- how the basic facts, principles and ideas of modern physics developed.
- who made the key contributions and something of their lives.
- process of science as illustrated by physics.
- how physics relates to the cultural and economic aspects of society.
- the effect of physics on other sciences
- the relationship and interaction between physics and contemporary technology.

Project Physics produced a vast array of teaching materials including 1) six student texts, called Student Guides (Concepts of Motion, Motion in the Heavens, Energy, Waves and Fields, Models of the Atom, and The Nucleus), 2) Physics Readers (articles and book passages related to the topics in the Student Guides), 3) Laboratory Guide (student experiments), 4) laboratory equipment, 5) film loops, 6) films, and 7) a teacher's guide [30].

PSSC Physics and Project Physics were the two major physics curriculum projects developed with funds from the NSF. Physics enrollments continued to decrease during the period of time that these courses were developed and thereafter. However research results showed that the courses were effective in improving students understanding of physics, and ability to accomplish high cognitive tasks.

4.2 Curricular Reforms at the College Level

The current state of the physics curriculum is considered distressing by many in the discipline. For example, only 24% of high school physics students take some form of high school physics compared to 54% of students taking chemistry and 93% taking biology [31]. Robert Hilborn, in an article published in the APS's Forum of Education's (FEd) Spring 1996 Newsletter, commented on the condition:

> That means, even with the most optimistic estimates, that fewer than half of the students entering college have any background in physics. The implications for all college science courses are ominous. Many of the students will be innocent of basic physical principles such as conservation of energy and momentum; they will lack the sharp problem solving and math skills that re often honed by physics courses, and their knowledge of electricity and magnetism, not to mention simple circuits, will close to zero [32].

He goes on to comment that only 3% of the students who take calculus-based physics in college go on to take another physics class. Including those who take algebra-based physics, these statistics are reduced even further. So, how does one balance the needs of potential majors with the needs of students in other fields? In other words, how do we avoid alienating students with other interests and recruit and retain more students into the physics major?

Hilborn went on to state:

> The American educational system is not a monolith. That is both a strength and a weakness, but it is a fact. It requires programs to encourage both small-scale innovations that may later grow into major national reforms… and also broad initiatives… that can more directly effect systemic changes [33].

Such is the basis of the following discussion of current curricular reforms in physics.

With this, the following discourse will focus on two of the most influential curricular reforms at the introductory level—the Introductory University Physics Project (IUPP) of the American Institute of Physics (AIP) and funded by the NSF, and Workshop Physics of Dickinson College and Tufts University funded by the Department of Education’s Fund for the Improvement of Postsecondary Education. Both of these reforms share the common thread of reducing the material covered in the introductory sequence adhering to the adage that “less is more” and, in their own ways, try to internalize physics in the students by asking the same questions that reformed the secondary curriculum; “how do we know…?”, “why do we believe…?”, and “what is the evidence for…?” Addressing another area of concern in physics education is the issue of undergraduate recruitment and retention. Several examples of programs to increase the production of physics majors will be discussed.

4.2.1 The Introductory University Physics Project (IUPP)

The IUPP began in 1987 when John Rigden, the editor of the *American Journal of Physics* at the time, procured a small grant from the NSF to begin a new curricular physics reform at the introductory level and from this beginning, the American Association of

Physics Teachers (AAPT) and the APS have cosponsored the project. One of the driving forces behind developing a new introductory curriculum included bringing the content of the curriculum up-to-date with the current state of the discipline. That is, very few textbooks from the time incorporated any topics of modern physics which was pioneered in the early twentieth century and well established. The physics curriculum was nearly a century behind the discipline! To remedy this, the IUPP set out to identify effective instructional concepts through the evaluation of several course models which implemented the IUPP operating principles.

The development of the IUPP was very methodical and included many established physicists' input such as Donald Holcomb, Charles Misner, Robert Resnick and representatives from the NSF, APS, AAPT and the AIP. From the inaugural meeting of the IUPP's steering committee in 1987, several operating principles emerged:

> 1. Contemporary physics should be a prominent part of the course content.
> 2. The total course content should be reduced relative to the status quo. Fewer topics should be covered in more depth. [the "less-is-more" philosophy.]
> 3. The course content should have coherence. The topics making up the subject matter of the course should be linked by a story line. The phrase "story line" describes a single or small number of organizing themes which can be used to link sequential segments of the course into a pattern with structure evident to the student.
>
> Although very difficult to attack effectively via a physics content-centered project, keep a fourth guideline in mind:
>
> 4. The needs of all student constituencies in the introductory course should be met. (By "constituencies" is meant several varieties of identifiable student groups—different academic interest groups such as pre-engineering or pre-medical students, students with differing levels of background in physics or mathematics, students from underrepresented ethnic groups, or women.) [34]

Recognizing that less than 5% of students ever go on to take another physics course, the IUPP concerned itself with those students whom the introductory course would be their terminal course in physics. It also set itself out to assure that the needs of minority students in physics were not being ostracized by the curriculum, namely women and minority ethnic groups.

Planning for the IUPP proceeded to the selection of several course models to be tested in the classroom. These consisted of the “Six Ideas that Shaped Physics” (the laws of physics are universal, interactions are constrained by conservation laws, some quantities are relative, but laws are absolute, fields are dynamic, matter has wavelike characteristics, and some energy flows are irreversible), “A Particle Approach to Physics,” “Structures and Interactions,” “Physics in Context.”

“Six Ideas that Shaped Physics” was authored by Thomas Moore of Pomona College and investigates each concept as organizing principles and are discussed for four to five weeks. “A Particles Approach to Introductory Physics” was developed by a team at the US Air Force Academy led by Rolf Enger and James Head. This model addresses physics on the small scale and treats physical systems as either a single particle or a system of particles. “Structures and Interactions” was authored by Dwight Neuenschwader of Southern Nazarene University and is based on the following principles: 1) where feasible, concepts are first introduced in the laboratory, 2) there is a strong emphasis on explicit instruction in the art of mathematical modeling, and 3) structures in nature (atoms, galaxies, etc) and their interactions inspire a spiraling story with recurring themes. “Physics in Context” was conceived by Jorge Barjas of the Metropolitan University and Ridgen at the AIP and authored by Lawrence Coleman, David Griffiths, and Ridgen. The ‘context’ enters as an organizing and limiting theme—real life situations, such as global warming, are introduced with the physical principles underlying them.

These models were tested in classroom trials in the early 1990’s. Faculty involvement and interaction made the evaluation of the models possible. For instance, members of the development teams for the four course models, instructors preparing for the next round of trials and an instructor from each of the previous trials met before the implementation of the next round of trials to give feedback and suggestions to the instructors preparing for the next round of trails [35].

The results of these evaluations showed that the operating principles produced improved conceptual gains in students in all models. The product of the IUPP is novel in some aspects in that the end product was a group of instructional concepts instead of instructional materials (i.e. the IUPP produced no textbooks, etc).

4.2.2 Workshop Physics

Workshop Physics is a unique approach to the presentation of physics as it departs the farthest from traditional lecture and recitation methods that have dominated the history of the physics curriculum. In this reform, lecture is basically done away with—replaced with short lectures on topics which are then directly investigated by students in laboratory settings equipped with computers and scientific apparatus. Classes meet three times a week for two hours each meeting. The program, like the IUPP, attempts to reduce the amount of material covered in order to gain a deeper understanding of the topics selected. The theory directly behind workshop physics is that with a fundamental understanding of a few basic physical concepts, transference to understanding other physical situations can be attained without formal education.

In order to make the curriculum more digestible by students, about 25% of the topics were eliminated from the introductory sequence. According to Priscilla Law, developer of Workshop Physics at Dickinson College, it is not critical which concepts are deleted since several other institutions that adopted the program chose to delete other material than she had in order to meet the specific needs and special interests of the students without consequence [36].

The role of the instructor in Workshop Physics is to help create the learning environment, lead discussions and encourage students to engage in reflective discourse with one another. This is clearly following from the experiential philosophy of John Dewey. The students play an equally important role as the instructor in workshop physics. Many educators believe that peers are often more helpful than instructors in stimulating original thinking and problem solving in students and this is also a contention of Workshop Physics.

Many of the laboratory exercises are carried out with the use of computers but great care has been taken to keep the curriculum focused on using computers to aid in the education of physics and not using physics in the education of computer science. To achieve that aim, complex mathematical programs such as Mathematica are used rarely. For the most part, the use of spreadsheets are used to analyze data and are even used for some simple numerical integration.

A survey of student attitudes towards the study of introductory physics among 1600 students at 16 colleges revealed the following findings regarding Workshop Physics (as quoted by Laws in a *Physics Today* article on Workshop Physics):

- Students at Dickinson College express a preference for the workshop method of teaching.
- In Workshop Physics, a greater percentage of students master concepts that are considered difficult to teach because they involve classic misconceptions.
- Performance of Workshop Physics students in upper-level physics courses and in solving traditional textbook problems is as good as that of students who took our traditional lecture courses.
- We know by observation that students who complete Workshop Physics are considerably more comfortable working in a laboratory setting and working with computers.
- Students in Workshop Physics rate a whole range of learning experiences more highly than their cohorts taking traditional courses. [37]

Admitted shortcomings include:

- Some students complain that Workshop Physics courses are too complex and demand too much time.
- A small percentage of students thoroughly dislike the active approach.
- The conceptual gains of students are sometimes disappointing in some areas.
- It is difficult to learn to teach in a workshop format. [38]

4.3 Undergraduate Recruitment and Retention of Physics Majors

Over the past 15 years or so, the production of physics bachelor degrees has been falling off to levels of were seen in the late 1950's, only in the past few years to remain relatively constant [39]. Since "a healthy physics profession must be rooted in the entire society, rather in scientists alone, and because ultimately it is legislators, voters, teachers and other non-scientists who will determine the fate of physics" [40], it is important that their be scientific literacy and openness among the citizens of this society. The decline in the interest of physics in this nation's young, as evidenced in the production of physics bachelor degrees, shows that there is much room for improvement in the physics curriculum. The physics curriculum, especially at introductory levels, plays a vital part in educating the non-scientist of physics (since it is often the introductory course that serves as the terminal course in physics) and it is here that many students with undecided majors will decided for or against majoring in physics. Therefore, it is the introductory physics curriculum that is the focus of physics major recruitment and retention efforts along with literacy efforts for the non-major.

One fine example of these efforts is the literacy, recruitment and retention curriculum reform at the University of Arkansas. This department implemented a revitalized introductory physics sequence for future physicists called University Physics II, which was supported by the NSF. The core of this program is to instill an appreciation for science in students by closely tying theory and lab together and unite these experiences with applications students are familiar with, thereby showing the relevance of every topics. It is reported by Gay Stewart, a professor at the University of Arkansas that:

> Preliminary results finds a large majority (approximately 95%) of the students liked the new course and felt they learned more from it. Most students rank the class in the top 10-30% of all classes taken in college. The course typically has an enrollment of approximately 150 engineering and science majors [41].

Stewart also adds that these students were also at least as positive in their attitudes toward science as those students in the IUPP.

As a result of this new program, the average physics baccalaureate graduation rate is up from 2.5 per year during 1990-1997 to about 15 per year beginning in 1998. These numbers were increased by introducing a physics major for those students who do not intend on working in the physics field directly, but could use a physics background in other fields such as business, journalism, K-12 teaching and medicine. This track is a bachelor of arts (BA) program that requires substantially less physics than the bachelor of science (BS) track that the University Physics II program leads up to (24 credits in physics and 40 credits, respectively). This allows students the flexibility to pursue other majors in conjunction with physics as well as opening a gateway to the BS program for students that would not have otherwise considered physics as a major. Roughly one-third of the graduating seniors elect the BA program in physics [42]

The University of Arkansas has also reached out to the non-scientists by instituting a set of courses that approach science as a human endeavor within its cultural context: Physics and Human Affairs, and Survey of the Universe. There is little math in these courses reducing the content to concepts and these concepts are related to such things as global warming, energy resources and nuclear weapons (in the Physics and Human Affairs course).

These new non-technical courses have enticed 40% of non-science majors on the campus to take at least one of these courses at some point in their undergraduate career [43].

Stewart also documented how vital faculty are to the development and implementation of the new curriculum at Arkansas:

> To institutionalize the changes necessary to maintain and continue to build the undergraduate program required the cooperation and support of the entire faculty. This was made possible by careful consideration of manpower and research interests. While it is necessary to have someone who mentors the students and makes sure the curriculum is serving them well, it is essential to have faculty support [44].

Similar programs are developing around the country. A program at Lawrence University is focusing on the entire program more than the curriculum specifically. This makes the faculty role in the program prominent. In the words of David Cook of Lawrence University at an invited presentation at the April Meeting of the APS, 2001:

> Major improvement [in the recruitment and retention of physics majors] cannot be accomplished in a year or two by one or two [faculty] members working alone, and it must impact the entire departmental program, not just it curriculum and certainly not a few courses [45].

Another program at Brigham Young University focuses on orientation activities, advisement, promoting student-student interactions, faculty mentoring, undergraduate research, teaching emphasis and department culture [46].

5 Summary

From this review, it is plain to see that faculty play the lead role in curriculum development but professional emphasis on hard research has all but eliminated the discussion of their contribution from the literature. It is seen that physics faculty are highly educated, those in two-year colleges work tirelessly towards the education of their students while finding funds for research monopolizes the attention of young faculty at four-year universities. Regardless, faculty are evidently still concerned with educational matters since there have been many efforts to engage students *in* physics, to treat students as apprentice physicists and to internalize concepts by asking the critical questions of "*how do we know…?*", "*why do we believe…?*", and "*what is the evidence for…?*" Physics has been moved from traditional presentation and accepting physical laws at face value to active interaction of students in the physical world to discover physics for themselves. With this internalization, transference can occur bringing the official curriculum into the extracurricular where new concepts can be rationalized without formal education.

This is the handiwork of the physics faculty even though, all-in-all, undocumented and unappreciated.

6 Bibliography

[1] A. Hobson. “Teaching Versus Research: Why We Don’t Reach Out”, Forum on Education Newsletter, (August 1999).

[2] R. Ivie, K. Stowe, R. Czujko, “2000 Physics Academic Workforce Report”, AIP Pub. Number R-392.4, (March 2001).

[3] J. Tavel, “Two National Surveys of Two-Year College Physics Faculty”, *The Phys. Teach.* **33**(2): 85-90; (February 1995).

[4] Reference 2

[5] Reference 2

[6] Reference 2

[7] R. Ivie, K. Stowe, “Women in Physics, 2000”, AIP Pub. Number R-430, (June 2000).

[8] Reference 7

[9] Reference 2

[10] P. J. Mulvey, S. Nicholson, “Enrollments and Degrees Report”, AIP Pub. Number R-151.36, (March 2000).

[11] Reference 2

[12] Reference 3

[13] Reference 3

[14] Reference 3

[15] Reference 3

[16] Reference 3

[17] R. Czujko, D. Kleppner, S. A. Rice, “Their Most Productive Years: Young Physics Faculty in 1990”, *Phys. Today* **44**(2): 37-42; (February 1991).

[18] Reference 17

[19] Reference 17

[20] Reference 17

[21] G. G. Wubbels, J. S. Girgus, “The Natural Sciences and Mathematics”, in *Handbook of the Undergraduate Curriculum*, J. G. Gaff & J. L. Ratcliff (Ed.), (Jossey-Bass, San Francisco, 1997).

[22] C. D’Avanzo, “What College Science Faculty Can Learn About Change”, *J. of Col. Sci. Teach.* **29**(2): 126-131; (November 1999).

[23] A. B. Arons, “Uses of the Past - Reflections on United States Physics Curriculum Development, 1955 To 1990”, *Interchange*, **24**(1-2): 105-128; (1993).

[24] D. M. Donahue, “Serving Students, Science, or Society—The Secondary-School Physics Curriculum in the United States, 1930-65”, Hist. Edu. Quart. **33** (3): 321-352; (1993).

[25] U. Haber-Schalm, “The PSSC Course”, *Phys. Toda*y **20**(3): 26-20; (March 1967).

[26] G. J. Posner, Analyzing the Curriculum, 2nd Ed. “Curriculum Organization”, 157-160; (McGraw-Hill, 1994)

[27] Reference 25

[28] Reference 24

[29] Reference 23

[30] G. Holton, “Harvard Project Physics”, *Phys. Today* **20**(3): 31-34; (March 1967).

[31] R. C. Hilborn, “On the Importance of Undergraduate Science Education”, Forum on Education, (April 1994).

[32] Reference 31

[33] Reference 31

[34] D. F. Holcomb, “The Introductory Physics Project”, Forum on Education Newsletter, (November 1994).

[35] J. S. Rigden, D. F. Holcomb, R. DiStefano, “The Introductory University Physics Project”, *Phys. Today* **46**(4): 32-37; (April 1993).

[36] P. W. Laws, “Calculus-Based Physics Without Lectures”, *Phys. Today* **44**(12): 24-31; (December 1991).

[37] Reference 36

[38] Reference 37

[39] M. Neuschatz, P. J. Mulvey, S. Nicholson, “Physics and Astronomy Senior Report: Class of 1998”, AIP Pub. No. R-211.30, (December 1999).

[40] G. Stewart, “Growth in Undergraduate Physics at the University of Arkansas”, Forum on Education Newsletter, (Fall 2000).

[41] Reference 40

[42] A. Hobson, “Growth in Undergraduate Physics at the University of Arkansas, Part II”, Forum on Education Newsletter, (Spring 2001).

[43] Reference 42

[44] Reference 40

[45] D. M. Cook, “Strengthening Undergraduate Physics at Lawrence University’, Presented at the *APS April Meeting*, (Washington, D.C., April 2001).

[46] R. S. Turley, “Recruitment and Retaining Physics Majors at Brigham Young University”, Presented at the *APS April Meeting*, (Washington, D.C., April 2001).