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Guest Editorial:
Sharing our Work*

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As science teachers and science educators, we belong to a unique group of individuals. We strive to improve education by talking critically about ideas related to science education, making observations about teacher and student learning, and collecting data that we hope will shed light on the learning and teaching process of teachers and students. As we communicate with each other, we suggest innovations and confirm existing practices. Communication occurs in different venues and includes participating in informal discussions, conferences, and meetings, as well as writing e-mails, posting our findings on web pages, and publishing our work. This last venue of communication--the publishing of our work--is the focus of this editorial.

Academics and educators are often funded by public dollars. We share our work with each other in order to advance the field, but also because we have a responsibility to do so. By communicating frequently, we can build upon the knowledge base in science education, identifying and exploring ideas as they are put forth. The sharing of our work is an important component of our job, and in certain fields we can obtain long-term employment (tenure) that ensures the exploration and dissemination of novel ideas.

One of the most common ways that we share our work is through our publications. Many of us publish in notable journals such as the *Journal for Research in Science Teacher Education*, the *International Journal of Science Education*, or the *Journal of Science Teacher Education*. However, we may have also published in electronic journals such as the *Electronic Journal of Science Education* (http://ejse.southwestern.edu) or *Contemporary Issues in Technology and Teacher Education* (http://www.citejournal.org). While all of these journals contain research in science education, the last two are published electronically and are designated as open-access journals. Open-access electronic journals provide us with new opportunities in the field that we have not experienced with traditional for-profit publications. Unfortunately, our perceptions about electronic publishing sometimes limit our participation in this venue. In an effort to initiate a dialogue about the potential of open-access publications, I would like to explore some “myths” about electronic and open-access publications.

Let me begin with the first Myth, which stems from our lack of understanding of electronic publishing.

Myth 1 - Electronic journals have limited capabilities

Actually, electronic journals are unlimited in what they offer authors and readers. John Cannon, founder and editor for ten years of this journal, has often reminded authors that they can post pictures, video and complex graphics on the electronic web-site. While paper journals are well suited to tables, black and white pictures, simple graphics and text, it is difficult, expensive and sometimes impossible to place multiple color pictures, streaming video, or audio in a paper document. For those of us in science education, seeing or hearing data enhances our understanding of the author's point. For example, instead of reading about a teaching event in India, we can watch streaming video and audio of the teacher in order to understand her use of STS in the classroom. Transcripts that show how we analyzed the collected data can follow. Instead of a textual description, the reader can now access every aspect of the teacher's practice and the method of analysis. With such opportunities, our understanding of science education can move to a new level.

I especially enjoy the easy access to the electronic journals that I read. After a few strikes on the keyboard, I can summon a peer-reviewed article and all of the supporting documentation to the screen in front of me. I can find a copy of an article that was submitted just two months earlier, which means I have access to some of the most current work available. But it doesn't stop with just viewing the article. I can now download the paper onto my palm pilot and read it at my leisure. Staying current in the field is no longer tied to my ability to walk to the library and read or copy articles, which may have been in queue for over a year and in review for another year. In this venue I get information as soon as it can be reviewed and posted electronically. More importantly, I don't have to pay a fee to view an article if my library doesn't subscribe to this journal.

While more for-profit publishers are providing electronic articles with supporting documentation, their articles are still published on a set cycle, conforming to some degree to the guidelines for publishing in paper (e.g., length). Additionally, one often has to pay (e.g., $10, $20, or $25) for access if one does not subscribe to the journal or if the journal is not in the holdings of the local library.

With most open-access electronic journals, articles can be posted or retrieved quickly without cost. Such articles can be linked to additional resources, are not limited by length, and can have various forms of information attached. They can even be modified easily for those with disabilities. This is just a short list, as open-access electronic publishing is limitless, not limited.

Myth 2 - Electronic journals lack rigor

What makes a journal rigorous is the quality of articles published and the process by which articles are selected. A journal published electronically can be just as rigorous as a paper journal.

The American Educational Research Association (AERA) has a Special Interest Group (SIG) for editors or those associated with scholarly, peer-reviewed, open-access electronic journals (http://aera-cr.asu.edu/ejournals/index.html). A quick look down the list reveals some notable electronic, open-access publications. More importantly, the number of journals is substantial (over 150) and increasing yearly.

Perhaps these journals are not considered as rigorous as paper journals when it comes to promotion and tenure decisions or merit allocations. But that is changing. While I can't speak for other universities, I do know that electronic journals are considered for promotion, tenure and merit in some departments at the University of Texas and in my current department in Arizona State University. Top e-journals, like *Educational Policy Analysis Archives* (http://epaa.asu.edu/epaa/), which was edited by Gene Glass and belongs to the above-mentioned AERA SIG, are certainly equivalent to top paper journals. Just as a point of reference, *Educational Policy Analysis Archives* gets over

3,500 hits per weekday, which translates into 17,500 hits per week. Furthermore, one article that is not even seven years old is over a milliondownloads! What for-profit paper journals get looked at 3,500 times a day? What recent for-profit journal article has been looked at close to a million times?

Rigor is about the work and the process by which it is reviewed, not the medium in which the work is published.

Myth 3 - Electronic journals are difficult to maintain

If you haven't talked about paper journals and for-profit publishing with your local librarian lately--you should. Your librarian will more than likely tell you about the escalating cost of for-profit journals, the housing constraints associated with paper journals, and the number of for-profit, paper journals that have been canceled over the years. In education, our journals are not as expensive as those in sciences. However, our journals are increasing in cost and can easily contribute to a strained library budget. For example, the *Journal of Science Teacher Education* was initially managed by the Association for the Education of Teachers of Science (now, Association for Science Teacher Education). As an association owned journal, a library would pay $45 for a subscription. When the journal was moved to a for-profit publisher, the journal price increased over twelve years to a current library rate of $245 for four issues. This price is what a library would pay for our journal--if they wanted to expand their holdings. Most libraries, however, have contracts that allow them to select a number of journals for a set price over several years. The "bundling" practice purports to lower the overall cost of journals and give libraries more journals. Unfortunately, this does not always happen.

In 1988, nineteen years ago, The University of Texas paid approximately $2.3 million for the journals in the library system. In 2005, The University of Texas paid approximately $7.3 million for the journals in the system. In the last fourteen years, The University of Texas library has cancelled approximately 7000 journals, and there is a small cancellation project of 500 journals underway. To avoid the reduction of additional journals for just this year, the library was given special one-time funding totaling $1.2 million (totaling $8.5 million for the year). Needless to say, these funds may not be available in upcoming years, which will result in additional paper/publisher-based journals being placed on the "UT periodical reduction plan."

The expense of journals has forced universities to support electronic publishing. It's ultimately cheaper for a university to pay for technology support staff to oversee electronic journals than to purchase more journals. Several library and university-based groups actually support electronic publication and provide paper options, and make these options available to associations, organizations, or people wanting to start their own journals. These groups include HighWire press (http://highwire.stanford.edu/), The Berkeley Electronic Press (http://www.bepress.com/alljournals.html), or even SPARC (http://www.arl.org/sparc/). The attractiveness of these no- or low-cost publishers has resulted in significant increases in the journals they produce, thus reducing some of the additional costs libraries have each year.

More importantly, electronic journals don't require much space or maintenance. Gene Glass published his journal from a computer on the floor of his office. In contrast, most universities face a shortage of space with their ever-expanding collection of paper journals. One computer can easily hold all of the journals that would ordinarily fill the floor of a library with compact shelving. When I asked Gene Glass about the difficulty of accessing and maintaining his journal, he indicated that his computer was low maintenance and that he could easily access any of the articles he had published over the last 10 years. In addition, he can easily monitor the number of visits to his journal and the activity of article downloads. According to Gene, there have been no major computer problems and no problems with computer hackers. After all, as Gene said, "Who wants to hack into a scholarly open-access journal on educational policy?"

Electronic journals are not difficult to maintain. They cost less, occupy less space and give more people access to information.

Myth 4 - Electronic journals hurt organizations

Organizations become stronger with electronic publishing. Instead of relying on the profits of the journal, associations have to rely upon the quality of their work and the participation of their membership. Members, for example, join the organization because of the visibility of the work and the benefits of belonging to the association. Organizations that have turned from organized publishers to open-access publications are making money by increasing their membership. Additionally, these organizations are increasing their international readership. Ultimately the association can cost less to join, which makes it more affordable for new and international members.

More importantly, it is clear that the international community wants access to our work in education. Unfortunately, the cost of our journals can be excessive to our counterparts in developing countries. For instance, in some countries $200 could cover the costs of materials in a laboratory as opposed to a journal subscription. Gene Glass has evidence that our international colleagues are eager to access our knowledge base. When he made one change in his electronic journal--he used a downloadable pdf file format--his international readership increased to 30%. Every day, over a 1,000 hits come from international educators. I should add that the two other journals that Gene "competes with" –the main journals in his field –have approximately 500 yearly subscriptions.

The international community wants to engage with us in educational scholarship, but we are not yet accessible to our colleagues in other countries. You may have recently heard about the memorandum written by members of the faculty senate at Stanford. This group passed a resolution stating that their libraries should support affordable journals and acquire journals on a title by title basis. The change would move the libraries away from the practice of bundling, which can actually cost a library more over time. If the Stanford action is a sign of the times, associations with no-cost or low-cost journals will be given preference when it comes to adding a subscription to a library. As associations turn to low-cost methods for publishing, their work will be more affordable for those with limited budgets.

Expensive journals limit the dissemination of information by faculty and staff from associations and universities or colleges. Associations or universities/colleges support faculty and staff so that they may contribute to the knowledge base in teacher education; when they publish in for-profit journals, they are only reaching those institutions who can afford to purchase the journals.

Myth 5 – The best way to share information is through publisher based journals

Well not quite. Published journals are only accessible if libraries have them in their holdings. Open-access electronic journals are available to anyone who can access the internet. More importantly, most publishers hold the copyright on the contents of the journal and the associated electronic forms, which means the publishers own the copyright of the work that was produced by authors who were funded with public dollars. A typical publishing contract gives the publisher sole and exclusive right to publish their material throughout the world during the term of the copyright. Some publishers will allow academics and researchers to post their work on their own web-page, but there are often restrictions on the posting of this work (e.g. format, length, duration). Most publishers prefer authors not to post published work, as it takes away from the revenue associated with article downloads. This is revenue that goes primarily to the publisher, with little or none going back to the author, university, or association. Ultimately, if we want to share our work, we have to ask for permission from the publisher or pay the publisher to use our work. This is not difficult, but why do we have to ask to share our work, or be told by the publisher that we can share our work, when our work was funded by public dollars with the intent of advancing the profession? When I give my copyright away, the publisher owns my work, not the institution or organization that supported my work.

Ultimately, sharing our work requires that we find venues that allow for the greatest access to our work in the most affordable manner. By sharing our work broadly, we will continue to impact science education.

As a tenured faculty member at a research university, I am convinced that we need to share our work in ways that increase access and that support the building of knowledge in our profession. In the upcoming years, more of my work will be found in open-access journals, and I will be joining the editorial boards of open-access journals or association-owned journals. Additionally, I will continue to work with my colleagues to raise their awareness about electronic options. In doing this, my contributions to research and service, which are supported by public funds, will have the greatest possible reach. Finally, instead of giving the copyright of my work to a publisher, which limits the circulation of my work, I will ask that the copyright of my work go to my institution or back to myself, so that I can post my research in an accessible location.

I hope that we will all consider how we share our work and the ways in which we can enhance the circulation of our work to impact teachers, schools, and policy. After all, we academics and educators have a responsibility to disseminate our work.

Acknowledgements

I wish to thank Gene Glass for a wonderful conversation about his journal, Peter Veronesi and Johns Stiles for stressing that e-journals can easily be modified by those with disabilities, Henry Hagedorn for raising my awareness about this crisis in academics, and Dennis Dillion for sharing the problems that The University of Texas system is facing.

* Association of Science Teacher Educators Presidential Address, January, 2005; South West Association of Science Teacher Educators Invited Address, April, 2005

Perceptions of Head Agricultural Science Teachers Regarding Problems and Challenges of Vocational Agriculture Delivery in Secondary Schools in Delta State, Nigeria

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Abstract

The purpose of this study was to determine the perceptions of head agricultural science teachers regarding problems and challenges of vocational agriculture delivery in secondary schools in Delta State. The population included all agricultural science teachers (n = 915) in Delta State from which a purposive sample of 370 agricultural science teachers were drawn. A total of 290 (80%) copies of a 47 item-questionnaire distributed were correctly filled and used for this study. Data were analysed with frequencies, percentages, means and standard deviations. The result showed among others that conducting regular continuous assessment/tests was the most frequently used technique of vocational agriculture delivery among agricultural science teachers while poor funding of vocational agriculture in secondary schools and keeping abreast with developments in the field of agriculture and communication of such developments to students were the most perceived problems and challenges of vocational agriculture delivery in secondary schools. The study recommended that these perceived problems and challenges by head agricultural science teachers be built into short-period in-service education and refresher programmes of serving teachers in agricultural science.

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Introduction

Teaching of agricultural science at the secondary school requires a sound background in theory and practical aspects by the teachers of agriculture. The new 6-3-3-4 system requires that agriculture be taught as pre-vocational subject at the primary and junior secondary schools and as a vocational subject in senior secondary school level (National Policy on Education, 2004). The 6-3-3-4 educational system in Nigeria includes six years of primary education, three years of junior secondary (pre-vocational) education, three years of senior secondary education and varying tertiary education period of not less than four years. Although this system of education has remained fairly constant since it became government policy, there have been some slight modifications in government commitment towards the provision of basic education to Nigerians. For instance, the scope of the Universal Basic Education (UBE) programme has been extended to nine years, which includes six years of primary education and three years in junior secondary school.

The delivery of vocational agriculture at the senior secondary level should not be handled as a science per se but rather as a vocational subject for acquisition of practical agricultural skills for meaningful living (Obi, 2005).

Olaitan (1997) maintained that the basic goal of our National Policy on Education is to make education both functional and utilitarian. Ikeoji (1999) reported that vocational education is borne out of the need for the system to make its products useful to themselves. The Federal Ministry of Education (as cited by Obi, 2005) stated that the objectives of agricultural education at the senior secondary should include;

1) to stimulate and sustain students interest in agriculture;
2) to enable students acquire useful knowledge and practical skills in agriculture;
3) to prepare students for further studies in agriculture; and
4) to prepare students for occupations in agriculture.

In addition to this Yoloye (1984) outlined the aim of vocational education in Nigeria as:

1) to provide people who can apply scientific knowledge to the improvement and solution of environmental problems for use and convenience of humanity;
2) to provide the technical knowledge and vocational skills necessary for agricultural, industrial, commercial and economic development; and
3) To provide young men and women with an intelligent understanding of the increasing complexity of technology.

Observation has shown that as laudable as the objectives of agricultural and vocational education in Nigeria are it may be impossible to achieve them due to poor delivery process of the programme and inappropriate method of evaluating the performance of students in vocational agriculture at the senior secondary school (Ikeoji, 1997a, 1998). Martin and Odubiya (1991) reported that the primary role of vocational agriculture teachers has always been to help students to learn knowledge and skills in agriculture.

Several researches have shown that many teachers of agriculture at the secondary school leave the profession early in their life (Myers, Dyer and Washburn, 2005;Heat-Camp and Camp, 1990,1994). Myers et al 2005; Camp, Broyles and Skelton, 2002; Mundt and Connors, 1999; and Veenman, (1984) have conducted studies on the problems of beginning teachers of agriculture. These problems of beginning teachers include classroom management and student discipline, balancing work and personal life, managing stress, lack of preparation time at beginning of school year, time management, and motivating students. Others were dealing with individual differences, assessing students work, relationships with parents, organization of class work, inadequate teaching materials and supplies, and dealing with problems of individual students (Myers, et al 2005; Mundt and Connors, 1999; Nicholas and Mundt, 1996; Mundt, 1991; Heath-Camp and Camp, 1990; Barrick and Doerfert, 1989; Veenman, 1984)

Several lapses associated with the organisation of vocational agriculture in secondary schools in Nigeria have also been identified. The curriculum objectives have been found to be too broad; there is the inability of the policy to state general aim of vocational education (Olaitan, 1992; Egbule, 1998; Obi, 2005). Other lapses include inability to identify areas where practical skills are to be developed (Obi, 2005), unspecified evaluation system (Egbule, 1998, Ikeoji, 1998); cases of duplicated topics and poor programme delivery system (Egbule, 1998); lack of instructional aids and materials for vocational agriculture delivery; lack of means and ability to provide recommended guest lecture visits and excursions (Obi, 2005, Olaitan, 1997). Egbule (1998) noted that the teaching and learning activities of vocational agriculture at the secondary schools are grossly insufficient to elicit the desired level of initiative and creativity in students. It noted that the recommended instructional strategies is full of "showing", 'telling' and 'observing' with a few cases of 'doing' and 'practice' thus contradicting the recommended 'learning by doing' and 'guided discovery' instructional strategies (National Policy on Education, 2004). Cases exist of poor performance of candidates who enrolled in agricultural science examinations (Mamman, 2000). Studies have also shown that graduates of vocational agriculture in senior secondary schools in Nigeria have often not been able to take up paid jobs at the completion of their secondary education thus defeating the goal of vocationalisation of secondary agriculture (Olaitan, 1997; Okorie, 2000; Obi, 2005; and Ikeoji and Agwubike, 2006).

Theoretical Framework

The theoretical framework for this study is hinged on the model for the study of classroom teaching as developed by Mitzel (Dunkin and Biddle, 1974; Osborne and Hamzah, 1989; Smith, Kistler, Williams, Edmiston and Baker, 2004). The model according to Dunkin and Biddle (1974) contain four classes of variables namely presage, context, process and product variables. The presage may include his personality, preparation, general characteristics, background, competencies and inadequacies, teacher-education experiences (Smith, et al 2004) and teacher properties (Mitzel, 1969). The context variables address the student characteristics and the classroom environment (Mitzel, 1969). Process variables show the interaction or interrelationship between the teacher and the student (Dunkin and Biddle, 1974). Smith et al, (2004) reported that all activities within the classrooms are considered process variables. The product variables are those associated with the effects of instruction (Mitzel, 1969; Dunkin and Biddle, 1974). Mitzel's model recognises the presage variables as fundamental in understanding classroom problems and challenges using the experience of the teacher. The experience of the classroom teacher tends to affect the classroom environment (context), interaction between the teacher and the students (process), and the effects of the instruction (product) (see figure 1)

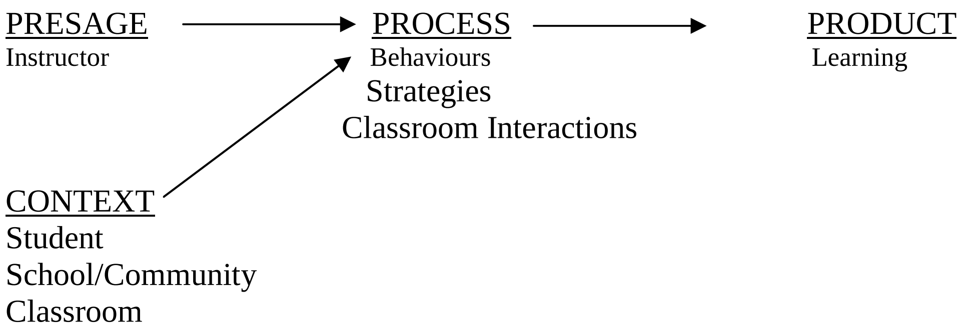

Fig: 1 An illustration of the Mitzel's model for the study of classroom teaching.
after Dunkin and Biddle (1974)

This study revolves around the presage variables of the Mitzel's model. A study of the problems and challenges of vocational agriculture delivery will improve the efficiency of the teacher and in turn improve students' achievement. It is believed that an articulation and identification of problems and challenges of vocational agriculture delivery in secondary schools by head agricultural science teachers with their wealth of experience will help in repositioning the vocational agriculture curriculum for pre-service and in-service vocational education teachers' preparatory programme planning and implementation. Head agricultural science teachers as used in this study refers to the most senior agricultural science teachers in each of the secondary schools studied. Seniority here is based on years of teaching experience. Every secondary school in Delta State secondary school system recognizes one most experienced agricultural science teacher as the head agricultural science teacher for a particular secondary school.

Literature reviewed so far studied problems of beginning agricultural education teachers abroad. No study of this kind has been conducted in Delta State especially that addressing the problems and challenges of vocational agriculture delivery as perceived by head agricultural science teachers.

Purpose and Research Questions

The purpose of this study was to determine the perceptions of head agricultural science teachers regarding problems and challenges of vocational agriculture delivery in secondary schools in Delta State. The following research questions were developed to guide the study:

1. What were the demographic characteristics of head agricultural science teachers in secondary schools in Delta State?
2. What techniques of teaching were adopted by vocational agricultural science teachers in secondary schools in Delta State?
3. What were the problems and challenges of vocational agriculture delivery in secondary schools in Delta State as perceived by the head agricultural science teachers?

Methods and Procedures

This study was conducted across all the secondary schools in Delta State, Nigeria. The research design chosen was a survey. The study included all agricultural science teachers from the 370 public secondary schools in the State where agricultural science is taught (N = 915). The sample included purposively selected 370 heads of departments of agricultural science, one from each school. The most senior agricultural science teacher in each school was taken as head agricultural science teacher.

A 47 item self-administered questionnaire was prepared and used to collect data from the respondents. The five point Likert-type scale instrument sought information on the demographic characteristics of the teachers, the teaching techniques adopted and perceived problems and challenges of vocational agriculture delivery in secondary schools. After a pilot test, the instrument was adjusted to the present form in which it was used to collect data for the study. Expert panel drawn from Vocational Education Department, Agricultural Education Unit, Delta State University, assessed the instrument for content validity. Sections B and C items of the instrument registered reliability (Cronbach's Alpha) coefficients of 0.78 and 0.92 respectively.

Questionnaire copies were distributed through each school's principal from the Ministry of Education in the process of submitting their monthly returns. The principals were asked to administer the questionnaire on their head agricultural science teacher who should return it through him the next month. A reminder was sent back to the head teachers at the end of the first month to remind those who had not returned the completed copies. After the second reminder, a total of 290 copies were correctly filled and returned. This gave a return rate of 80%. The copies were collated and analysed using frequencies, percentages, means and standard deviations.

Results and Findings

A total of 202 (69.66%) secondary school agricultural science teachers in Delta state sampled were teaching in the rural areas while the remaining 88 (30.34%) of them were found in urban schools (see Table 1). No respondent was in the age range of 20 – 30, while 25(8.62%) were in the age range of 31 – 40. Majority of the head teachers, 189 (65.17%) were in the range of 41 – 50 years; while 76 (26.21%) were 50 years and above. There were more female head agricultural science teachers (175, representing 60.34%), while 115 (39.66%) were males. No head teacher had teaching experience of 1 – 5 years, while 26 (8.97%) had experience of 6 – 10 years. Eighty-seven (30.00%) head agricultural science teachers had between 11-15 years teaching experience, while 72 (24.82%) had experience of between 16 to 20 years. Fifty-eight (20.0%) were in the teaching experience range of 21-25 years with the remaining 47 (16.21%) having teaching experience of 25 years and above.

Table 1. Demographic Characteristics of Head Agricultural Science Teachers (N = 290).

Characteristics		Number	Percentage	
Location				
	Urban	88	30.34	
	Rural	202	69.66	
Age				
	20-30 years	-	-	
	31-40 years	25	8.62	
	41-50 years	189	65.17	
	Above 50 years	76	26.21	
Mean	age			46.75
Gender				
	Male	115	39.66	
	Female	175	60.34	
Teaching Experience				
	1 –5 years	-	-	
	6-10 years	87	30.00	
	11-15 years	72	24.82	
	16-20 years	58	20.00	
	Above 25 years	47	16.21	
Mean	teaching experience			17.37

As indicated in Table 2, conducting regular continuous assessment/test was perceived as most effective technique of vocational agriculture delivery adopted by the teachers in secondary schools (*M = 4.93, **SD =0. 25). This is closely followed by the use of lecture approach (M = 4.86; SD = 0.35). The use of subject matter approach (M = 4.08; SD = 1.18) and use of discussion approach (M = 4.08; SD = 0.80) were all accepted as techniques adopted for vocational agriculture delivery in secondary schools in the state. The other fifteen items on Table 2 were perceived by the head teachers as not effective vocational agriculture delivery techniques adopted in Delta State secondary schools. They include learning-by-doing approach (M = 1.10; SD =0.30), use of guest lecturers to cover technical areas (M =1.31; SD = 0.46), use of community-based-materials for teaching (M = 1.33; SD = 0.47), making students spend ample time with professional persons as a way of mentoring them (M = 1.38; SD = 0.49); using problem solving approach (M =1.48; SD = 1.10); arranging visits to commercial farms (M = 1.84; SD = 0.94), using case studies approach for teaching (M = 2.08; SD = 0.94), use of local extension officers to teach special subject matter areas (M =2.19; SD 1.13), use of supervised/occupational experience approach (M = 3.16;SD =1.13); using life experiences as examples (M =3.28; SD = 1.36), use of demonstration (M = 3.37; SD = 1.31), and organisation of agricultural shows and exhibitions (M = 3.42, SD = 1.04).

Note: ***M**=mean; **SD=standard deviation*

Table 2. Perception of Head Agricultural Science Teachers on Effective Techniques of Vocational Agriculture Delivery Adopted in Secondary Schools in Delta State (N = 290).

Techniques		**M**	**SD**
1.	Conducting regular continuous assessment/tests	4.93	0.25
2.	Use of lecture approach	4.86	0.35
3.	Subject mater approach	4.38	1.18
4.	Use of discussion approach	4.08	0.80
5.	Organisation of agricultural shows and exhibitions	3.42	1.04
6.	Use of demonstration	3.37	1.31
7.	Using life experiences as examples	3.28	1.36
8.	Use of supervised agricultural/occupational experience approach	3.16	1.13
9.	Use of local extension officers to teach special subject matter areas	2.19	1.13
10.	Using case studies approach to teaching	2.08	0.94
11.	Arranging visits to commercial farms	1.84	0.94
12.	Using group work approach	1.64	1.10
13.	Using inquiry approach	1.48	0.82
14.	Using problem-solving approach	1.41	0.81
15.	Making students spend ample time with professional persons as a way of mentoring them	1.38	0.49
16.	Use of community based materials fro teaching.	1.33	0.47
17.	Use of guest lecturers to cover technical areas	1.31	0.46
18.	Use of guided-discovery approach	1.17	0.53
19.	Learning-by-doing approach	1.10	0.30

Note: 5=Strongly Agree, 4=Agree, 3=Uncertain, 2=Disagree, 1=Strongly Disagree

Table 3, revealed that the respondents perceived poor funding of vocational agriculture in secondary schools (M =4.93,SD = 0.25) as the most challenging problem of vocational agriculture delivery in secondary schools. The second most accepted problem and challenge was keeping abreast with developments in the field of agriculture and communication of such developments to students (M = 4.69; SD = 0.50). Others include contending for adequate time in the school time table (M = 4.56; SD =0.77), conducting evaluation of teaching and learning outcomes under the present system (large number of students in classroom) (M = 4.44; SD = 1.09) pressure on teachers and students to excel in what is tested and not what is functionally relevant (M = 4.26; SD = 1.26), administration of vocational agriculture by non specialists (M = 4.14; SD = 0.35); utilization of alternative resources and improvisation of teaching materials (M = 4.10; SD= 1.35) and others (see Table 3). The mean and standard deviation ranged between

(1.41 to 4.93) and (0.25 to 1.97) respectively. The least challenging problem identified was lack of basic knowledge of the syllabus (M = 1.41; SD = 0.81)

Table 3: Problems and Challenges of Vocational Agriculture Delivery in Secondary Schools as Perceived by Head Agricultural Science Teachers (N=290)

Perceived problems and challenges	M	SD
1. Poor funding of vocational agriculture in secondary schools	4.93	0.25
2. Keeping abreast with development in the field of agriculture and communication of Such developments to students	4.69	0.50
3. Contending for adequate time in the school time table	4.58	0.77
4. Conducting evaluation of teaching and learning outcomes under the present system (large number of students in a classroom)	4.44	1.09
5. Pressure on teachers and students to excel in what is tested and not what is functionally relevant	4.26	1.26
6. Administration of vocational agriculture by non specialists	4.14	0.35
7. Utilization of alternative resources and improvisation of teaching materials in teaching vocational agriculture	4.10	1.35
8. Lack of basic teaching and learning aids (Farm tools, land, and other laboratory equipment)	4.09	1.50
9. Lack of interest on the part of the students	4.04	1.46
10. Lack of required material and resources for vocational agriculture delivery	3.98	1.49
11. Understanding the purpose and objective of teaching vocational agriculture in secondary schools.	3.93	0.97
12. Examination and certification of candidates based on 90% external testing and 10% practical examination.	3.76	1.68
13. Harmonization of the aims of prevocational practical agriculture at the junior secondary level with that of senior secondary level	3.73	0.94
14. Inability of the curriculum to transmit employable skills to students	3.71	1.63
15. Overlap of syllabus content in agriculture and other science subjects.	3.58	1.31
16. Combining teaching vocational agriculture with other administrative jobs	3.51	1.64
17. Effectiveness in teaching practically usable skills.	3.46	1.55
18. Ambiguity of purpose and objectives of vocational		

	agriculture in secondary schools	3.39	1.97
19.	Piecing together competencies involved in teaching the right attitudes and values	3.04	1.30
20.	Ability to identify areas in which practical skills should develop	2.97	1.61
21.	Poor sequencing of topics in the syllabus	2.96	1.61
22.	Keeping abreast with latest scientific knowledge available	2.31	1.58
23.	Combining teaching vocational agriculture with personal engagements	2.24	1.33
24.	Lack of basic knowledge of the syllabus	1.41	0.81

Note: 5=Strongly Agree, 4=Agree, 3=Uncertain, 2=Disagree, 1=Strongly Disagree

Discussion of Findings

Results presented above have shown that 69.66% of the respondents teach in rural secondary schools signifying that majority of the secondary schools were located in the rural areas of the state. Also noticeable is the fact that the average teaching experience of the head teachers was 17.37 years. The explanation to this may be that to become heads of agricultural science department in their various schools required that the teacher should have had many years of experience in the teaching of agriculture.

Conducting regular continuous assessment/tests was perceived by majority of the respondents as the effective technique of vocational agriculture delivery adopted by teachers of agriculture in the secondary schools. This finding is consistent with those of Gordon (1998) who reported that vocational teachers' attitude towards assessment were viewed as positive, suggesting that vocational education teachers rely on the information generated by tests to provide them with the basis for improving instruction. Also Scharfer and Lissitz (1987) concluded that although teachers may be ill trained to use accepted measurement practices, they see assessment as an important part of their professional role and have a positive attitude towards it. However, the high level of agreement may necessarily not be that it was the best technique of vocational agriculture delivery, but it may be as a result of the State's policy on education that teachers should regularly conduct assessment/tests on instructions given to students to ascertain their level of progress. The Delta State Ministry of Education has an effective and well co-ordinated mechanism for ensuring that primary and secondary schools perform regular tests at specified periods in a term, and these tests are recorded as part of the students' final performance. Over time this practice has become part of all primary and secondary school teachers including agricultural science teachers.

The use of lecture approach was also identified as an effective technique used by agricultural science teachers in Delta State. This tends to corroborate the findings of Osborne (1989) and Egbule (1998). Osborne (1989) reported that although generally accepted components of problem solving in teaching are being used by agricultural science teachers, lecture-discussion is also often used by teachers to present problems solutions or answers to students. Furthermore, Egbule (1998) also reported that the instructional strategies adopted in vocational agriculture are full of 'showing', 'telling' and ‘observing’. ‘Learning-by-doing’ approach and use of guided discovery approach were hardly used by teachers of agriculture in secondary schools in the State. This however, runs counter to the use of ‘learning-to-doing, and ‘guided discovery’ approach recommended by the National Policy on Education (2004). An explanation to this trend may not be unconnected to the findings of Ikeoji and Agwubike (2006) who reported that one of the major problems facing new agricultural science teachers in Delta State was that of coping with large agricultural science class sizes.

The problems and challenges identified in this study were those associated with head agricultural science teachers in secondary schools in Delta state. Poor funding of vocational agriculture in secondary schools, keeping abreast with development in the field of agriculture and communication of such developments to students, administration of vocational agriculture by non specialists; inability of the curriculum to transmit employable skills to students; lack of required material and resources for vocational agriculture delivery; lack of interest on the part of students; pressure on teachers and students to excel in what is tested and not what is functionally relevant among others were the major perceived problems and challenges of vocational agriculture delivery in secondary schools identified in this study. Problems and challenges identified here are not consistent with those of beginning agriculture teachers documented (Mundt and Connors, 1999; Myers, et al, 2005; Camp, et al, 2002 and Veenman, 1984). The findings also contrast with those documented in that the areas not recognized as problems and challenges such as combining teaching vocational agriculture with personal engagements in this study was the major problem of beginning teachers of agriculture as shown in literature (Myers, et al, 2005; Mundt and Connors, 1999). This sharp contrast may not be unconnected with the use of head agricultural science teachers in the identification of the problems and challenges of vocational agriculture delivery. Experience of the head agricultural science teachers as observed in this study seems to have conditioned them to the teaching job and reduced problem areas from their perception. However, the most perceived problems of poor funding of vocational agriculture and keeping abreast with development in the field of agriculture are worthy of note. Delta State runs about 370 public secondary schools majority of which are in the rural areas. Much of the funds are provided by government, since primary and secondary education in Nigeria are tuition free. Public resistance has tended to restrain government from increasing school fees to be able to fund the schools better. Also the rural location of most schools compel teachers to live in rural areas which lack basic amenities like libraries, electricity and internet facilities. Teachers therefore find it difficult to keep abreast with developments in the field of agriculture.

Implications and conclusions

The perceptions of head agricultural science teachers have implications for organization of refresher programmes for serving teachers of agriculture. These perceived problems and challenges could be used to develop programmes for seminars and workshops for teachers and administrators in the field of agricultural education. This will help to improve on the performance of teachers of agriculture. Another implication is that the findings will aid in re-designing inservice educational curricula of teacher education institutions in the State.

Based on the results of this research, it is hereby recommended that:

1. The State Post-Primary Education Board (SPEB) should design programmes that will equip the State's teachers of agriculture in the use of the instructional strategies (i.e. learning-by-doing approach and the guided discovery approach) as recommended in the National Policy on Education (2004).
2. Regular seminars and workshops/symposia need to be organised to keep agricultural science teachers informed of latest developments in the field of agriculture and how best to communicate them to students.

3. The perceived problems and challenges should be built into short-period in-service education programmes of serving teachers in agricultural science.

The effect of these identified problems and challenges of head agricultural science on job performance is beyond the coverage of this study. On the basis of this, it is further recommended that a study be conducted in that direction.

References

Barrick, K.R., and Doerfert, D.L. (1989). Assessing performance and planning in-service needs of first – year vocational agriculture teachers. *Proceedings of the National Agricultural Education Research Meeting,* 16,10-14.

Camp, W.G., Broyles, T., and Skelton, N.S. (2002). *A national study of the supply and demand of teachers of agricultural education in 1999-2001*. Blacksburg, V.A: Virginia Polytechnic Institute and State University.

Dunkin, M.J. and Biddle, B.J. (1974). *The study of teaching*. New York: Holt, Reinhart and Winston, Inc.

Egbule, P.E. (1998). Fine-tuning the pre-vocational education programme delivery in Nigerian secondary school. *Nigerian Journal of Curriculum and Instruction*, 6(1), 86-91.

Gordon H.R.D (1998). Vocational education teachers' perception of their use of assessment methods. *Journal of Vocational and Technical Education* 15(1) 1 - 14

Heath-Camp, B., and Camp, W.G. (1990). Induction experiences and needs of beginning vocational teachers without teacher education background. *Occupational Educational Forum,* 19(1) 6 - 16

Heath-Camp, B., and Camp, W.G. (1994). Assistance needed and received by beginning vocational teachers. *Journal of Vocational Education Research,* 17(1), 35-52.

Ikeoji, C.N. (1997a). Improving the senior secondary certificate practical agricultural science test format: a basis for effective curriculum implementation. *Nigerian Vocational Journal,* IX, 5-10.

Ikeoji, C.N. (1997b). *Making senior secondary school agriculture truly vocational:* A paper presented at the international conference on crucial issues on Nigerian/African education, University of Nigeria Nsukka 15-18 April.

Ikeoji, C.N. (1998). Developing relevant psycho productive devices for evaluating vocational skills. *Nigerian Journal of Curriculum and Instruction,* 6(1), 81-85.

Ikeoji, C.N. (1999). Utilizing agricultural in Nigerian secondary schools and colleges. *Journal of Vocational and Adult Education*, 1(2), 165-172.

Ikeoji, C.N. and Agwubike, C. C. (2006). Approaches for effective vocationalization of secondary school agriculture in Nigeria: The views of agricultural science teachers in Delta state, Nigeria. *Journal of Agricultural Education and Extension,* 12(3), 213-222.

Ikeoji, C. N., and Agwubike, C. C (2006) Problems facing new agricultural science teachers in Delta State. *European Journal of Scientific Research* 13(2) 229 - 237

Mamman, M.G. (2000). Teacher education and teacher effectiveness. *Journal of Teachers and Teaching,* 1(2), 25-29.

Martin, R.A., and Odubiya, A.O. (1991). Perceptions of IOWA vocational agriculture teachers regarding methods used in agricultural education. *Journal of Agricultural Education*, 25(2), 13-17

Mitzel, H.E. (Ed). (1969). *Encyclopaedia of Educational Research*. New York: The Free Press.

Mundt, J.P. (1991). The induction year: a naturalistic study of beginning secondary teachers of agriculture in Idaho. *Journal of Agricultural Education*, 32(1), 18-23.

Mundt, J.P., and Connors, J.J. (1999). Problems and challenges associated with first years of teaching agriculture: a framework for pre-service and in-service education. *Journal of Agricultural Education.* 40(1), 38-48.

Myer, B.E., Dyer, J.E., and Washburn, S.G. (2005). Problems facing beginning agriculture teachers. *Journal of agricultural Education,* 46(3), 47-55.

National Policy on Education (2004). Lagos: NERDC Press.

Nicholas, L.S., and Mundt, J.P. (1996). Surviving first year of teaching: perceptions of critical competencies from four educational perspectives. *Journal of Family and Consumer Sciences Education*, 14(2), 23-39.

Obi, C.I. (2005). A critique of vocational agricultural education in Nigeria senior secondary schools. *Journal of Home Economics Research*, 6(2), 57-61.

Okorie, J.U. (2000). *Developing Nigeria workforce*. Calabar: Page Environs Publishers.

Olaitan, S.O. (1992). Review of technical and vocational education in Nigerian schools. *National School Curriculum Review Conference Proceedings*, Kaduna; 2nd-6th September 1991. Macmillan Nigeria Publishers Ltd., 250-258.

Olaitan, S.O. (1997). *Prevocational and vocational education in Nigerian secondary schools:* _ A paper presented at the International Conference on Crucial Issues on Nigerian/African Education, University of Nigeria, Nsukka 15-18 April.

Osborne, E.W. and Hamzab, R. (1989). Use of problem solving teaching among secondary agriculture teachers in Illinois. *Journal of Agricultural Education,* (fall), 29-36.

Scharfer W.D and Lissitz R.W (1987) Measurement training for school personnel: Recommendations and reality. *Journal of Teacher Education* 38(3) 57 – 63

Smith, J.H., Kistler, M., Williams, K., Edmiston, W., and Baker, M. (2004). Relationships between selected demographic characteristics and the quality of life of adolescents in a rural West Texas: community. *Journal of Agricultural Education*, 45(4), 71-81.

Veenman, S. (1984). Perceived problems of beginning teachers. *Review of Educational Research*, 54(2), 143-178.

Yoloye, E.A. (1984). Contemporary issues in implementing the national policy on educational. *Journal of NERA, 41(1).*

Creating Constructivist Physics for Introductory University Classes

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Abstract

We describe the setting and effectiveness of a constructivist, project-enhanced environment in an Introductory Physics course. Force Concept Inventory measurements show that students made significant gains in their understandings of mechanics concepts. Student interviews revealed that group project work assisted in students' assimilation of course material.

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Rationale

Research shows that students who are taught physics by traditional methods fail to learn essential physics concepts (Bowen, 1998; McCaskey & Elby, 2004; McDermott, Shaffer, & Somer, 1994; Mullins, 1998; Sadler, 1998). Most of this research has been done in university level, calculus-based physics courses. Our approach combines the demonstrated success achieved by research-tested, calculus-based physics with modifications made to adapt to algebra-based physics curriculum appropriate for use within high school classrooms (Wells, Hestenes, & Swackhammer, 1995) and within university physics classes for non-physical science majors. This modified curriculum replaces the traditional textbook-lecture-lab format with a hands-on, project-based laboratory learning environment. The curriculum was designed and developed by making use of the research on how people learn science (Bransford, Brown, & Cocking, 1999; Travis & Lord, 2004; Donovan & Bransford, 2004). We created a constructivist-based approach within our university Introductory Physics sections to test if this method made physics concepts visible and meaningful to students.

The purpose for these research-based modifications within our Introductory Physics classes was three-fold. Firstly, we wanted to observe similar success within our algebra-based physics courses (for non-physical science majors) to those calculus-based physics courses cited in the literature. Secondly, we wished to field test and refine this curriculum with university students prior to its enactment within a high school physics environment. And thirdly, the sections of Introductory Physics that were taught with this modified curriculum contained a large percentage of pre-service teachers. Therefore, we wanted these pre-service teachers to have a first hand opportunity to experience and hopefully find value in this non-traditional form of teaching so they might implement it within their future classrooms.

Constructivist Physics

To better understand our constructivist framework, we utilize Hoovers' (1996) definition of constructivist learning. "*Learning is active rather than passive…if what learners encounter is inconsistent with their current understanding, their understanding can change to accommodate new experience…they apply current understandings, note relevant elements in new learning experiences, judge the consistency of …emerging knowledge, and based on that judgment, they can modify knowledge*" (p. 1). Confrey and Kazak (2006) unpack "the grand theory" of constructivism in mathematics and science. According to Confrey and Kazak, constructivism concentrates on how "actions, observations, patterns, and informal experiences can be transformed into stronger and more predictive explanatory ideas through encounters with challenging tasks…constructivism recognizes the value of other forms of securing mathematical certainty, such as the coordination of representations, the identification of patterns, the recognition of similar ideas in apparently dissimilar settings (connections), the development and refinement of conjectures, and the applications of the ideas to other fields" (Confrey and Kazak as cited in Confrey and Maloney, 2006, p. 7). This idea of constructivism is very much in line with inquiry learning where students actively engage in an instructional sequence of purposeful events such as problem sensing, problem formation, search, and resolution (Siegel, Borasi, and Fonzi, 1998, Dewey, 1933).

Classroom environments that incorporate constructivism and inquiry into their daily organization can allow students the chance to 'think scientifically' (Polman, 2000) and to carry out investigations in a focused, collaborative, and meaningful manner. According to the National Science Education Standards or NSES (NRC, 1996), K-12 students "should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate…techniques to gather data, thinking critically…about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments" (p. 105). Although NSES describes the types of events that K-12 students should experience, we believe that similar opportunities should be afforded to university students.

Harwood (2004) developed a model for inquiry with the following essential components: (1) asking general questions; (2) defining a problem; (3) forming a question; (4) investigating the known; (5) articulating an expectation; (6) carrying out a plan; (7) examining results; (8) reflecting on findings; (9) communicating with others; and (10) making observations. Similar models have been documented in the literature (Llewlleyn, 2002; Borasi & Siegal, 1994). This model is not unique to only science, but is applicable to all disciplines.

Studies have shown that physics students taught with traditional methods fail to do as well as those students taught with constructivist, inquiry approaches, or what Hake (2000) defines as interactive engagement methods.

> *Interactive Engagement (IE) Methods* are those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on

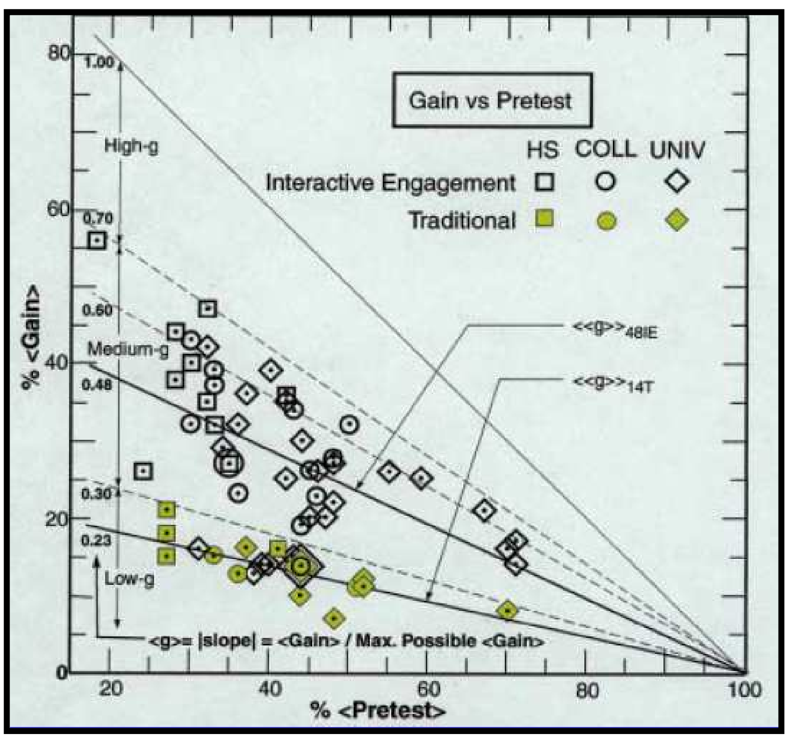
(always) and hands-on (usually) activities that yield immediate feedback through discussion with peers and/or instructors.

Traditional (T) Methods are those methods relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams. Traditional courses as those reported by instructors make little or no use of IE methods.

Crouch and Mazur (2001) found that both Calculus-based and Algebra-based Harvard University Introductory Physics courses taught through interactive peer instruction showed significant gains in students' conceptual understanding on the Force Concept Inventory (FCI) test (Hestenes, Wells, and Swackhammer, 1992a; 1992b). The average normalized gains of a traditionally taught Physics course is 0.23, and the average normalized gains of an Interactive Engagement taught course is 0.48 according to the Hake (1998 study) of six-thousand student surveys of test data for introductory physics courses.

Figure 1 displays a graph comparing gains in the FCI and Mechanics Diagnostic Test (Halloun and Hestenes, 1985) versus pre-test scores for both T (filled symbols) and IE (open symbols) methods (Hake, 1998). The graph includes scores obtained from high school, college, and university physics students. Clearly, IE students have greater normalized gains than their T counterparts at all levels of introductory physics.

Figure 1
Gain versus Pre-test Scores (Hake, 1998, p. 65)



For the past year, we have engaged in improving the constructivist inquiry model within our Introductory Physics classes. Although all three authors in previous years implemented pieces of inquiry within their courses, a focused effort on inquiry in

Introductory Physics emerged due to combined frustrations stemming from low achievement by students with non-physical science majors. We believe that in order for students to understand and be able to apply physical concepts, they need to engage in constructivist physics learning by becoming ***full participants*** during their investigations (Lave and Wenger, 1991).

Novak, Patterson, Gavrin, and Christian (1999) described a Just-in-Time Teaching method of teaching introductory physics blended with active learning. This type of IE method featured professors adapting their lectures to student learning difficulties on solving problems exhibited in electronic responses. This method also included collaborative recitations and students using an on-line homework system. Novak et al.'s IE method contained a significant lecture component and is designed to address large numbers of students in a lecture hall. Mazur (1997) discussed how an IE method of teaching can include a lecture demonstration that leads "into a question whose answer forces students to think about what they have just observed. Working the other way…ask students about a particular question and use a demonstration to answer it" (p. 27).

Both of these above examples are considered to be IE methods using the Hake definition; however, they are very different when compared to our IE method since our students are doing much more than problem reflecting and problem solving.

"Perhaps the most serious difficulty among introductory students is the failure of many to integrate related concepts. The lack of a coherent framework may pass undetected because mathematical manipulation often suffices for the solution of standard problems. To be able to apply a concept in a variety of contexts, students must be able to not only define the concept but also to recognize its relevance to a given physical situation. They are unlikely to develop this facility, however, unless they themselves have gone through the steps necessary to construct the concept" (McDermott, 1998, p. 2).

Through the constructivist, project-based approach, our students experienced the steps of question formulation and conjecture, experimental design, examination of results, and explanation of the physical phenomenon. In addition, final project work required our students to apply multiple physics concepts in a variety of contexts. We follow with a description of our research study and will map our results onto the Hake (1998) plot shown in figure 1.

Participants

For this paper, we will focus on two physics classes taught by the first and third authors having enrollments of 24 and 14, respectively. These 38 students (16 males and 22 females) had the following majors: 31.6% life science, 21.1% education, 15.7% pre-medicine or pre-pharmacy, 15.7% architecture, and 15.8% other, such as history, theater arts, Spanish, and undeclared. The student body consisted of 84.2% White, 7.9% African-American, and 7.9% other, and 36.8 % of the students were from the Honors College. There were a total of five freshmen, eleven sophomores, eighteen juniors, and four seniors.

Procedures

Our Introductory Physics sections were offered as four-credit hour classes but unlike the traditional sections that had three hours of lecture and two hours of laboratory, our sections were completely laboratory-based with individualized group “lectures.” Within these two physics sections, students (working in cooperative learning groups of four and five) learned by performing guided hands-on, minds-on, computer-based laboratory experiments. Using the constructivist method of instruction, students did not follow the regular textbook/lecture/lab format, but instead:

a) Made predictions that required them to examine their preconceptions about the phenomenon being studied.
b) Reflected on their observations and refined their conceptions.
c) Developed conjectures and generalizations based on their observations, and then designed their own experiments that would confirm their conjectures (Confrey and Kazak).
d) Performed experiments intended to verify predictions and applied their new understandings of the phenomenon to the solution of other related problems (Confrey and Kazak).
e) Worked on a final motion project of their choosing. For the final project, students videotaped various motions and analyzed the motion using VideoPoint (Lenox, 2002) software.

All laboratory activities within the Physics courses required students to keep journals and encouraged them to document their thinking processes in a narrative format. All groups were not necessarily working on the same inquiry experiment at the same time. Differentiated instruction was achieved by having students work in cooperative groups while the instructor circulated, facilitated group work, and provided “just-in-time” group lectures. Students could perform their inquiry experiments in multiple ways and had learning opportunities through assessing their own conjectures, by teaching their peers, and with individualized instructor attention when needed.

Research Focus and Methods

Our research study focused on an examination of whether physics concepts were made visible and meaningful to students using our constructivist technique of instruction. In addition, we detail our IE, constructivist approach through illustration of curricular units and group project work. Although other studies report that reform-oriented, constructivist methods of teaching physics are beneficial, few describe in depth exactly how the curriculum and instruction were enacted or showcase students’ voices regarding what they learned. In this paper, we compare our constructivist Physics FCI test results with the Hake (1998 study) of six-thousand student surveys of test data for introductory physics courses and provide detailed information regarding how we created our constructivist physics environment enhanced with final student projects.

This study is of a mixed method research design (Creswell, 2003). Data collections included students’ final projects and presentations, pre and post Force Concept Inventories (FCI), and end of course interviews. Through triangulation of the data

(Caracelli & Greene, 1997; Denzin & Lincoln, 1998), we analyzed students' understandings and knowledge constructions of physics concepts and applications.

The FCI, a multiple-choice diagnostic test, was developed by Arizona State University physicists Ibrahim Halloun and David Hestenes "to measure students' conceptual understanding of force and motion, topics that constitute 70-100 percent of the content of the first semester of virtually every undergraduate physics course" (Wyckoff, 2001, p. 311). The six Newtonian concepts tested in the inventory are (a) kinematics, (b) First Law, (c) Second Law, (d) Third Law, (e) Superposition Principle, and (f) kinds of forces (Hestenes, Wells, & Swackhamer, 1992b).

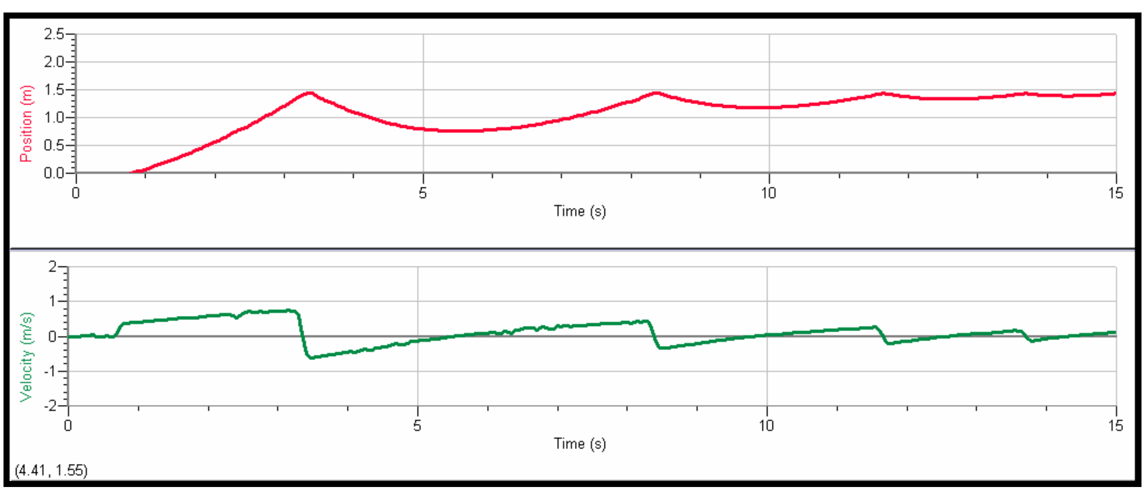
Along with the FCI data, eight student volunteers were interviewed by the first author. The interview protocol was open ended where students were simply asked to reflect on their experiences in this physics course and compare them with their other science learning opportunities. The open ended protocol also requested that students comment on their final projects. We follow with examples of the physics units and students' classroom work and final projects.

Examples of Physics Units

Throughout all curricular units, students used their previous knowledge and current observations to construct models for each area of investigation, giving them a context through which new understanding emerged. They developed scientific and mathematical procedures driven by observations which created authentic scientific and mathematical real world connections. They predicted and considered a range of various physical situations (see syllabus with scope and sequence in the appendix). After carrying out their experiments to test their predictions and examining their resultant graphical representations, students were able to discover functional relationships and equations that described the event.

Figure 2

Position versus Time and Velocity versus Time plots of a cart's motion moving up and down an inclined track.

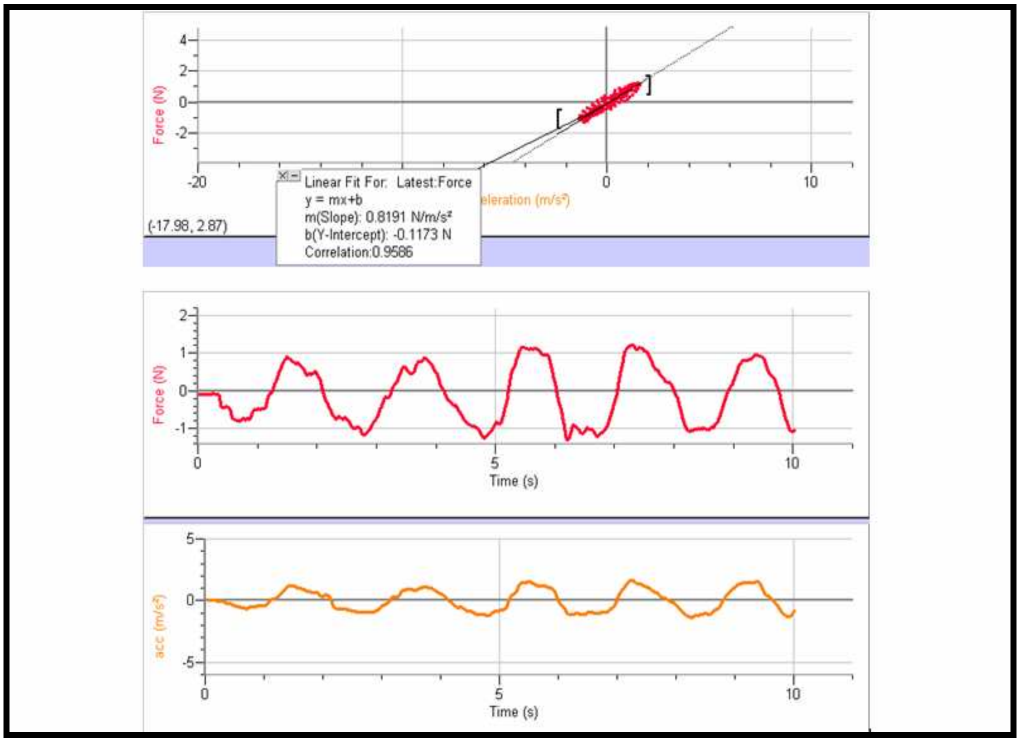


One of the first units enacted using this constructivist curriculum involved motion. Students learned multiple ways to explain one dimensional motion using words, graphs, and mathematical modeling. Students developed an intuitive understanding of position, velocity, and acceleration recognizing how graphs could be used to describe changes in position, velocity, and acceleration of an object. For example, Figure 2 displays plots that students created of position versus time and velocity versus time of a cart moving down an inclined track, hitting a bumper at the end of the track, moving back up the inclined track, and repeating the process several times losing energy after each bumper collision. Students became aware that the position versus time plot appeared to show a quadratic relationship between bumper collisions and began to interpret and to connect kinematic functional relationships with the physical cart's motion.

A following unit involved forces applied in one dimension. Students devised a method of applying a constant force to an object, created a scale for measuring force, and discovered a relationship between force and acceleration based on observations of an object's motion. For example, Figure 3 shows student-generated plots (using force and motion sensors) of force versus acceleration, force versus time, and acceleration versus time of a cart's motion loaded with a 500 gram mass along a flat track. Students observed the similarities between the force versus time and acceleration versus time plots. Students also were able to discover the linear relationship between force and acceleration when they plotted the force versus acceleration, and that the physical meaning of the slope was the mass of the loaded cart.

Figure 3

Force versus Acceleration, Force versus Time, and Acceleration versus Time plots of a cart's motion loaded with a 500 gram mass along a flat track.



As with the above examples, all other units in the curriculum involved similar student-centered explorations which used an interactive, constructivist format.

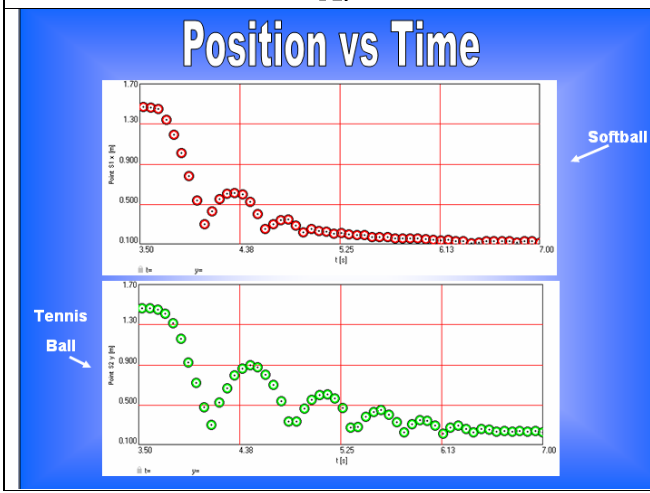
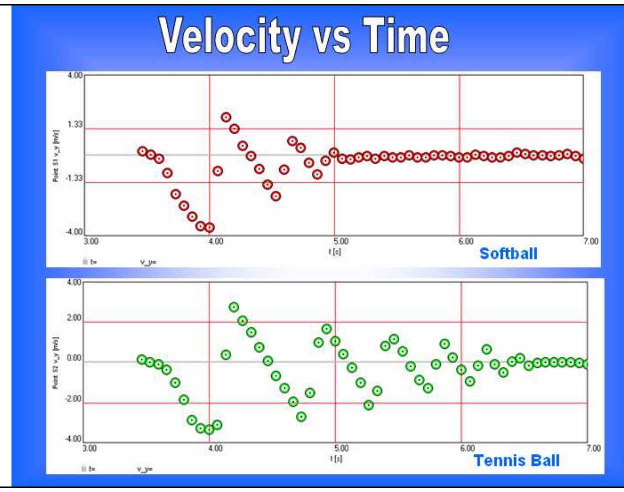
Inquiry Motion Projects

Students' final projects were used as a form of authentic assessment as well as a means of connecting much of what they had learned throughout the term (Wilhelm and Walters, 2006). For their final project, students formed research questions and videotaped a variety of motions that would assist them in answering their generated queries. In order to analyze these motions, students utilized VideoPoint software which allows the user to extract motion information from digital movies. Using this software package permits one to obtain position information from objects on a frame-by-frame basis. VideoPoint has tools to analyze the resulting data expressed as columns of numbers (position, velocity, acceleration, time) or as graphs. Student projects included analysis of bouncing balls, projectile motion of objects with and without parachutes, of a person moving down a playground slide, the motion of the computer created 'Mario' from the Nintendo software game, the balls' motion in Newton's Cradle (five balls hanging side by side in pendulum arrangement), and a golf swing. Two examples of the students' motion projects follow:

Bouncing Balls Project

A group of four students chose to videotape, examine, and compare the physical and mathematical motion of a softball and tennis ball that were dropped simultaneously and bounced several times on the floor. Figure 4 displays this group's graphed representations of each ball's position versus time and velocity versus time. Students explored each ball's location relative to the floor throughout its velocity versus time graph and noticed how quickly the softball dampened out when contrasted to the tennis ball. They also investigated and explained the physical and mathematical meaning of slope (acceleration) in the velocity versus time plot as well as the positive or negative values of velocity which indicated the ball's direction.

Figure 4
A. Graphed Representations of Position versus Time for the Bouncing Balls, B. Graphed Representations of Velocity versus Time for the Bouncing Balls.

A.	B.
	

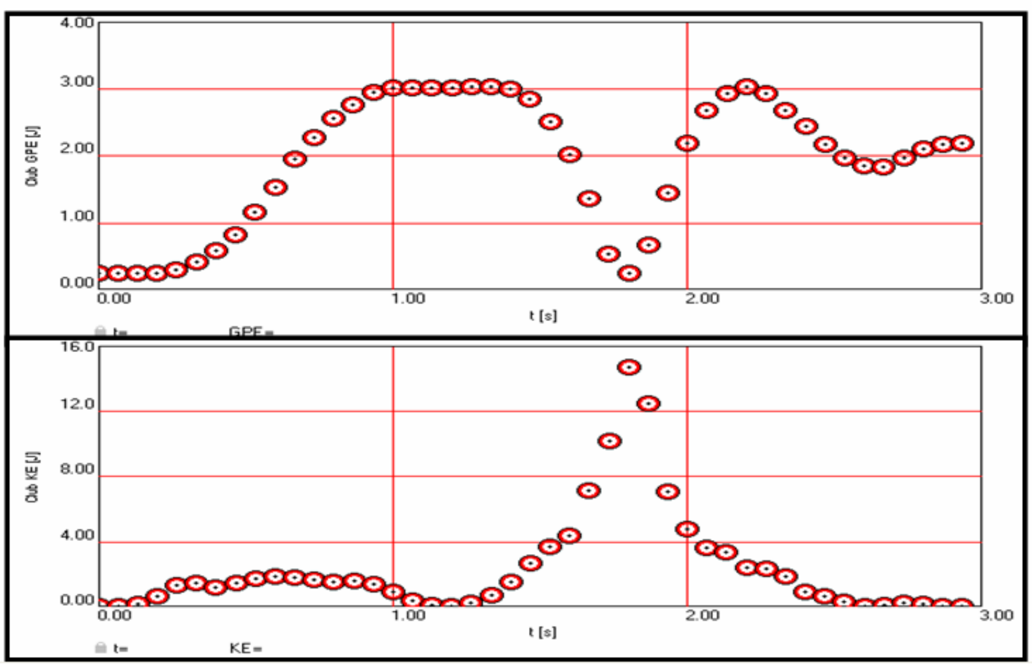
Golf Swing Project

Another group of five students was interested in the physics of sports. In particular, one group member recalled seeing a type of software available to golfers designed to improve their golf swing. The group decided to use VideoPoint software to analyze the motion of a group member's swing (see Figure 5).

Figure 5
Movie Clips of Student's Golf Swing

The golfing group focused their research on energy conservation. They examined the potential and kinetic energy of the golf club's head throughout the entire golf swing motion. They explained "*that as the club moves upward the potential energy increases and the kinetic energy decreases…As the club moves down, the kinetic energy increases as the potential energy decreases.*" They also presented graphical representations of potential energy versus time and kinetic energy versus time of the golf club head shown in Figure 6.

Figure 6
Top graph – Potential Energy vs. Time of Golf Club Head.
Bottom graph – Kinetic Energy vs. Time of Golf Club Head.



These two examples illustrate how students constructed and applied their newfound understandings to real life situations. Other student projects investigated accelerations in the microworld of a Mario computer game; periodicity, momentum conservation, and energy transfer in Newton's Cradle; the coefficient of friction between a person and a slide, and the effect of air drag on projectiles. Students conducted inquiry throughout this project work as they defined a problem to investigate, carried out a plan, made observations, collected data, examined findings, and communicated with others their final results. This entire act of constructivist inquiry was student-centered and the tools they used were student-contextualized. To complete their project work, students had to draw on all their experiences in order to fully interpret their observations. This is the essence of what real scientists do and this is the essence of our newly designed physics course.

Results

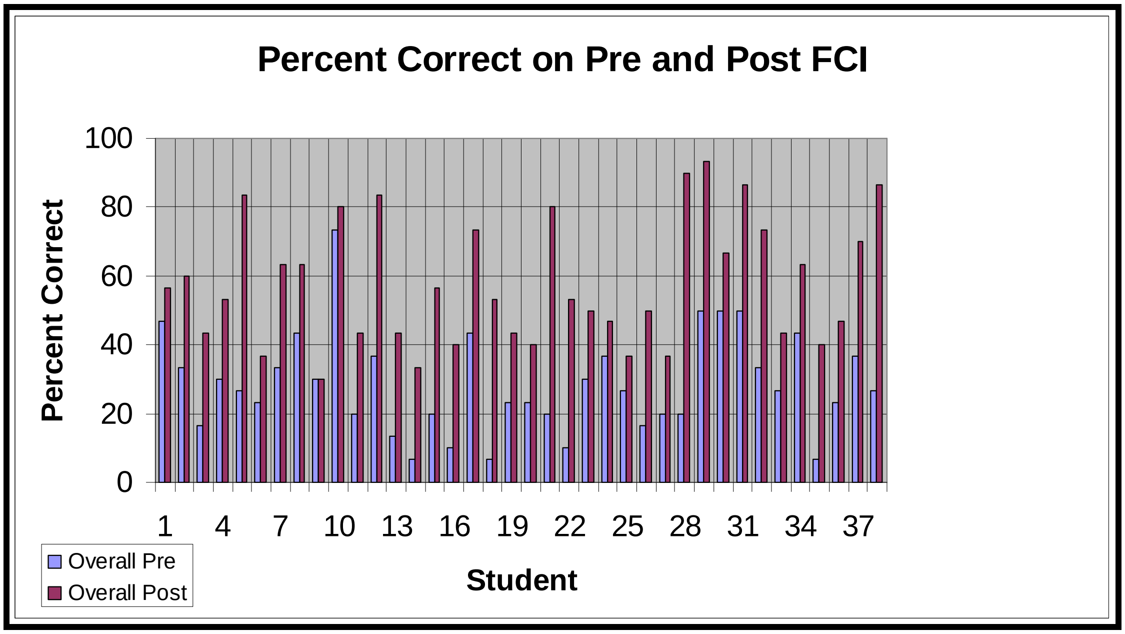
In order to assess the effectiveness of implementing this constructivist model within our physics courses, we administered pre and post FCI assessments to the 38 students. In addition to this measurement, we also interviewed eight students concerning their thoughts and views about the course in general and their group project work. Students volunteered for all interviews.

Our two Physics classes were given the pre-FCI prior to instruction and the post-FCI was given during the students' scheduled final examination. The mean pre-test score was 28.6 % correct with a standard deviation of 14.5 % and the mean post-test score was 57.7 % correct with a standard deviation of 18.2 %. A repeated measures analysis of variance (ANOVA) revealed a highly significant increase in understanding of FCI concepts upon completion of the Physics course, $F(1,37) = 126.655$, $p < .001$. The partial η^2 was .774, which indicates that approximately 77.4 % of the gain in FCI understanding can be directly attributed to the constructivist Physics course.

Figure 7 shows the percent correct on pre and post-FCI tests per student. Students made significant gains on 20 of the 30 multiple choice test items. The overall test average gain factor [(gain by student)/(possible gain)] was 0.41, which when plotted with their mean pre-test score of 28.6 % and mapped onto the Hake (1998) plot shown in figure 1, places our classroom data well within the Interactive Engagement group range. Of the ten test items that did not show significant gains, 70% included questions concerning circular motion and centripetal force.

Along with the FCI data, eight student volunteers were interviewed by the first author. The open ended interview protocol asked students to reflect on their experiences in this physics course and compare them with their other science learning opportunities. The protocol also requested that students comment on their final projects. Representative interviewees' statements follow.

Figure 7
Percent Correct on Pre and Post FCI per each student



Student Reflections on Physics Course

"This one made us actually think about what we're doing. Some (*science courses*) are telling us that this is how it is and then take formula and put in the numbers, but this one you actually saw why the formula makes sense" (Middle Level Mathematics/Science Pre-service Teacher).

"It was a lot different because in high school, they just lectured and pretty much just put the formulas up on the board and told us when to plug them in and stuff. It was just a lot different, (*in this class we*) like actually doing the experiments and come up with the formulas on our own. It was a lot more hands on….We had to figure it out more for ourselves more in this class instead of just being given it" (Middle Level Mathematics/Science Pre-service Teacher).

Representative Student Project Comments

One student expressed her interest in the course and in its project component, she explained, "I was more interested. This way I thought about it more. It was really cool to put everything we learned all semester into our project. It like put problems that we had been doing…into real life situations. It pulled everything that we did all semester into one real life problem" (Zoology Student and Playground Project Member).

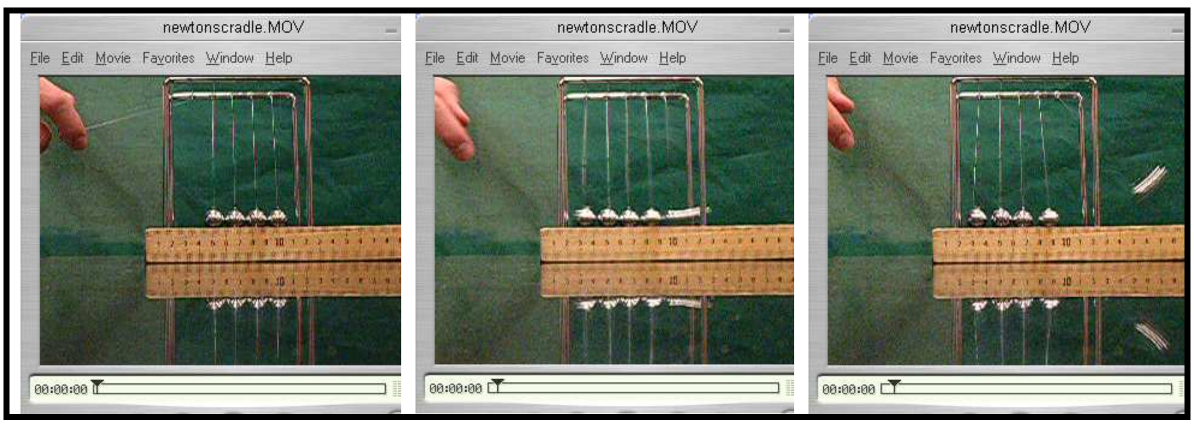
Below is an excerpt from the transcription of a student's final project comments that involved the analysis of Newton's Cradle (see Figure 8) with a focus on momentum conservation and energy transfer.

"Ok, Newton's Cradles. I was really fascinated with that one. I was always fascinated by the fact that energy is never just lost, but it's just being transferred from one ball to the other even though the other three (in the middle) are not moving. It's still transferring, which made me think of the other day. I asked my wife, 'what can we do to cars to keep them from crushing?' If in Newton's Cradles, one ball hits another and transfers the energy and knocks the other one off, if we could put some sort of like, ah, something to soak up that energy on the bumpers of the car, how would that affect it? If one car hit another one, is there any natural resource that we have that soaks up energy and just keeps it stored? I was trying to figure out what would make it safer."

This student's research project caused him to wonder about possible life applications linked to his new knowing and understanding of physical concepts like energy conservation, momentum conservation, and energy transfer. He speculated how one might make a futuristic car that would use the laws of physics to create safer automobiles.

Figure 8

Movie Clips of Newton's Cradle



Seven of the eight students interviewed clearly expressed their favored preference to the constructivist teaching approach. However, one student responded, "Personally, I like hands on, but I do better at having a lecture first because I learn by writing it down. I like having notes. I know how boring that sounds, but that's how I learn better by writing, so, it is easier for me that way." This particular student was a middle level mathematics/science pre-service teacher who made an average normalized gain score of .17 (less than half of the class average normalized gain score). The interviewer asked this student how she planned to teach her own future mathematics and science classes. She stated that she would incorporate a mixture of inquiry and straight lecture.

The interview results exposed the students' voices regarding this course and their project work. Students stated that this physics class made them "actually think" and "actually do experiments and come up with formulas on their own," and "put problems into real life situations." Both interview and project data illustrated how students applied their physics coursework to "real life situations," and even caused some "fascination" as they pondered such things as energy transfer.

Conclusion

This paper showed through students' project work, interview responses, and FCI results how using a constructivist inquiry method of teaching physics created relevance and meaningful learning for many students. The students participated in a classroom environment that provided a series of challenging tasks, the chance at posing conjectures, occasions for refining and/or altering prior understandings, and opportunities to apply their newfound understandings into novel situations (such as their project work)—all of which made the physical and mathematical concepts visible, connected, and useful. The Bouncing Balls group connected physics and mathematics as they conducted their project work and investigated the mathematical and physical meaning of slope (acceleration) in a velocity versus time graph as well as the positive or negative values of velocity which indicated the ball's direction. The Newton's Cradle group found the ideas of energy conservation and energy transfer useful, and one member imagined how he might design a safer vehicle. Other students voiced how physics taught in the constructivist manner meant they "had to figure it out more for ourselves," "come up with the formulas on our own," and "you actually **saw** why the formula makes sense."

Force Concept Inventory results revealed our students achieving a higher normalized gain score than those students taught in a traditional manner (when comparing our normalized gain score of 0.41 with Hake's, 1998, average normalized gain score of 0.23 for traditional groups). In addition, we found that our average gain factor of 0.41 versus our mean pre-test score of 28.6% (when mapped onto the figure 1 plot) fell well within the Interactive Engagement group range. Other FCI results showed our students had greatest difficulty on topics of circular motion, which we will need to further address in future courses.

This research is much more than a small verification study of Hake's large analysis of the six-thousand student surveys of test data that compared results of Interactive Engagement versus Traditional classrooms. What makes our study unique and educationally beneficial is that we provided descriptive information about our introductory university physics class that was designed with constructivist and project-based ideals. This information can assist educators in their own design of their constructivist science classrooms. Along the lines of Confrey and Kazak's "grand theory" of constructivism in mathematics and science, we reported our students' actions, experiences, inquiry tasks, and final project work. Students' final projects contained Harwood's essential inquiry components of formulating a question, carrying out a plan, examining results, reflecting on findings, and communicating with others. As prescribed by McDermott (1998), our students made connections among concepts and the real world as they worked through the steps of inquiry and participated in our constructivist, project-enhanced environment.

Our future goal is to implement a similar classroom experience within high school physics environments with this modified, constructivist, project-enhanced approach.

References

Borasi, R., and Siegel (1994). A first step toward a characterization of an inquiry approach for mathematics education. *L'Insegnamento Della Matematica E Delle Scienze Integrate*, 5 (17A-17B), 467-493.

Bowen, S. P. (Summer, 1998). TIMMS – An Analysis of the International High School Physics Test. *American Physical Society Forum on Education.*

Bransford, J. Brown, A., and Cocking, R. (1999). *How People Learn: Brain, Mind, Experience, and School.* National Academy Press, Washington, D. C.

Caracelli, Valerie J. and Greene, Jennifer C. (1997). Crafting mixed-method evaluation design. In J. C. Greene and V. J. Caracelli (Eds.), *Advances in mixed-method evaluation: The challenges and benefits of integrating diverse paradigms.* New Directions for Program Evaluation, No. 74. San Francisco, CA: Jossey-Bass, pp. 19-32.

Confrey, J. and Kazak, S. (2006). A thirty year reflection on constructivism in mathematics education in PME. *Paper presented at the 30th meeting of the International Group for Psychology of Mathematics Education (PME). Prague, Czech Republic. July 2006.*

Confrey, J. and Maloney, A. (2006). From constructivism to modelling. *Paper presented at the annual conference of the Middle-East of Science, Mathematics and Computing in Abu Dhabi, United Arab Emirates.*

Creswell, J. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage Publishing.

Crouch and Mazur. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics*, 69 (9), 970-977.

Denzin, N.K. and Lincoln, Y. S. (1998). *The landscape of qualitative research.* Thousand Oaks, CA: Sage Publishing.

Dewey, J. (1933). *How we think.* Boston: D. C. Heath.

Donovan, S., and Bransford, J. (2004). *How Students Learn: Science in the Classroom.* National Academy Press, Washington, D. C.

Hake, R. (1998). Interactive engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66* (1), 64-74.

Hake. R. (April, 2000). Towards paradigm peace in physics education research. *Paper presented at the Annual Meeting of the American Educational Research Association,* New Orleans, U.S.

Halloun, I. and Hestenes, D. (1985). Common sense concepts about motion. *American Journal of Physics,* 53, 1056-1065.

Harwood, W. (2004).A new model for inquiry. *Journal of College Science Teaching,* 33(7), p. 29-33.

Hestenes, D., Wells, M., and Swackhammer, G. (1992a). A Mechanics Baseline Test. *The Physics Teacher, 30,* 159-166.

Hestenes, D., Wells, M. and Swackhammer, G. (1992b). A Force Concept Inventory. *The Physics Teacher, 30,* 141-158.

Hoover, W. (1996). *Southwest Educational Development Letter*, 9(3), *Retrieved August 14, 2006, from the Southwest Educational Development Laboratory* website: www.sedl.org/pubs/sedletter/v09n03/practice.html.

Lave, J. and Wenger, E., *Situated learning: Legitimate peripheral participation.* Cambridge, MA: Cambridge University Press, 1991.

Lenox Softworks, VideoPoint Co-Founders: Frank DiCesare and Mark Luetzelschwab, MA, 2002.

Llewellyn, D. *Inquire Within*. Thousand Oaks, CA: Corwin Press, 2002.

Mazur, E. (1997). *Peer instruction: A user's manual.* Upper Saddle River, NJ: Prentice Hall.

McCaskey, T., and Elby, A. (2004). Belief versus "Understanding": Why do students "split" on the FCI? *Contributed talk presented at American Association of Physics Teachers National Meeting, Miami Beach, Flordia, January 2004.*

McDermott, L.C., Shaffer, P.S., and Somer, M.D. (1994). Research as a guide for teaching introductory mechanics: An illustration in the context of the Atwood's machine. *American Journal of Physics.* 62 (1), 46-55.

McDermott, L. (1998). Research in physics education. *American Physical Society News* 7(1).

Mullins, I.V.S., et al. (1998). *Mathematics and Science Achievement in the Final Year of Secondary School.* TIMMS International Study Center, Boston.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

Novak, G., Patterson, E., Gavrin, A., and Christian, W. (1999). *Just-in-time Teaching: Blending active learning with web technology*. Upper Saddle River, NJ: Prentice Hall.

Polman, J. (2000).*Designing Project-Based Science: Connecting Learners Through Guided Inquiry*. New York, NY: Teachers College Press.

Sadler, P. (1998, May). Misconceptions in Physics. *Talk to the Ohio Section of the American Physical Society*, Muncie, IN.

Siegel M. Borasi, R., and Fonzi, J. (1998). Supporting students' mathematical inquiries through reading. *Journal of Research in Mathematics Education*. 29 (4), p. 378-413.

Travis, H. and Lord, T. (2004). Traditional and constructivist teaching techniques. *Journal of College Science Teaching*, 34 (3), p. 12-18.

Wells, M., Hestenes, D., and Swackhammer, G. (1995). A modeling method for high school physics instruction. American Journal of Physics, 63(7), p. 606-619.

Wilhelm, J. and Walters, K. (2006). Pre-service Mathematics Teachers Become Full Participants in Inquiry Investigations, *International Journal of Mathematical Education in Science and Technology*, 37(7), p. 793-804.

Wyckoff, S. (2001). Changing the culture of undergraduate science teaching: Shifting from lecture to interactive engagement and scientific reasoning. *Journal of College Science Teaching*, 30(5), p. 306-312.

Appendix

Introductory Physics I

Course Description

Algebra and trigonometry based treatment of the laws of motion, energy, momentum, circular motion, gravitation, waves, and sound. Credit 4 hours.

The Nature of the Course: The course will be completely laboratory-based. (It will NOT be divided into Lecture and Laboratory.) Content will be learned through experimentation and projects. The focus is on understanding the experiments and on learning to develop models of physical phenomena based on experimental evidence. Answers to laboratory questions will be documented within a journal along with a recording of all thinking processes. There will also be readings, exercises, homework, and a final project.

Outcomes

The student will have:

1. Knowledge of basic processes, concepts and principles of the laws of motion, energy, momentum, circular motion, gravitation, waves, and sound;
2. Understanding of the concepts and laboratory techniques found in general physics;
3. Knowledge of metric measures;
4. Proficiency in organization and use of laboratory equipment;
5. Proficiency in process skills, including identifying and controlling variables, interpreting data, formulating conjectures and hypotheses, and experimenting.

Course Objectives:

Upon completion of this course, the student will be able to:

1. State the fundamental physical laws of motion, energy, momentum, circular motion, gravitation, waves, and sound;
2. Use algebra in solving problems in the fields mentioned in the objective above;
3. Use the concept of a vector along with basic trigonometry to solve a wide range of problems;
4. Utilize basic problem solving processes, including observation, inference, measurement, prediction, use of numbers, classifying and use of space and time relationships;
5. Use computers to perform laboratory experiments and analyze and graph data;
6. correctly use measuring devices and other equipment introduced in the lab;
7. Work effectively in cooperative group situations.

Methods of Accessing the Expected Learning Outcomes

Quizzes, two midterms, journal and homework assignments, pre-tests, post-tests, surveys, a final project, and one final exam which will assess your level of understanding of basic concepts, facts, discussed topics and reading material. Graded journal entries and homework assignments will be used to assess understanding of individual topics covered in daily discussions and pre- and post-tests will be used to assess gains in understanding over the extent of the course.

Pre-tests, post-tests and surveys: A general pre-test and a survey will be given at the beginning of the semester and some sections will start with pre-tests. In addition, a general post-test and survey will be given at the end of the semester.

Homework: Homework will be assigned each week. <u>Each homework assignment will include written work recording all thinking processes with each problem.</u>

Journals: All lab topics will be written in course journals.

Project: One project on motion analysis will be studied and presented in detail by each cooperative group.

Quizzes: There will be quizzes on content and process covered in class, homework, readings and exercises up to that point.

Exams: There will be two midterm exams and a final exam on content and process covered in class, homework, readings and exercises up to that point

Week of class	Topics
1	**Vectors and One-Dimensional Motion Graphing**
2	**One-Dimensional Forces and Motion**
3	**Gravitational Force and Two-Dimensional Motion**
4	**Newton's Third Law, Force Diagrams and Forces**
5	**Applications of Newton's Laws**
6	**Statics and Torque**
7	**Circular Motion**
8	**Work**
9	**Energy**
10	**Momentum**
11	**More Momentum**
12	**Waves**
13	**Sound Waves and Simple Harmonic Motion**
14	**Rotational Kinematics and Dynamics**
15	**Final Physics Project Presentations**

Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview

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Abstract

For the last five years we have used a semi-structured interview, which we refer to as the Teacher Beliefs Interview, to explore the beliefs of beginning secondary science teachers who were involved in different induction programs. Our initial questions focused on teacher epistemologies and probed the beliefs of beginning and experienced teachers, while our process of interviewing utilized methods common in qualitative research. In reviewing and refining our interview process, we developed maps that allowed us to describe and define various beliefs held by pre-service, beginning/induction, and experienced science teachers. Our current Teacher Beliefs Interview is based upon the analysis of semi-structured interviews with over 100 pre-service, induction, and in-service science teachers. Ultimately, these maps have allowed us to track the development of science teachers, while providing feedback regarding the effectiveness of our pre-service and induction programs.

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Introduction

Over the years, educational researchers have explored a variety of constructs pertaining to teachers in order to help improve the structure and impact of teacher education programs. Areas of study include teacher practices, teacher attitudes, and teacher knowledge. Another area of focus--and the subject of the present article--is that of teacher beliefs. Early researchers considered beliefs to be the information a teacher held about a person, a group of people, a behavior or an event (Fishbein & Ajzen, 1975). Within the last 15 years, understanding and describing teacher beliefs has become a priority for educational researchers. These personal constructs can provide an understanding of a teacher's practice: they can guide instructional decisions, influence classroom management, and serve as a lens of understanding for classroom events (e.g. Jones & Carter, 2007; Pajares, 1992; Richardson, 1996). A substantial body of research has been generated in this domain (see Jones & Carter, 2007; Richardson, 1996).

In science education, research on beliefs has been linked to the use of inquiry, national reforms, or constructivist practice in the classroom (e.g., Hashweh, 1996; Tsai, 2002; Wallace & Kang, 2004; Yerrick, Parke, & Nugent, 1997). Wallace and Kang's (2004) study of six experienced teachers, for example, revealed how the beliefs teachers held influenced the degree of implementation of inquiry and laboratories in their science classrooms. Hashweh's (1996) study of 35 science teachers found that constructivist beliefs corresponded with constructivist behaviors. Yerrick, Parke, and Nugent (1997) concluded that science teachers needed to explore and examine their underlying beliefs about teaching and learning inquiry in order to assimilate an accurate representation of this reform into their conceptual framework. For science educators, understanding the beliefs of teachers is essential and important if teacher education programs are going to support the on-going development of science teachers (Keys & Bryan, 2001).

In our exploration of teacher beliefs, we have tried to understand how beliefs are modified as a teacher progresses from his or her pre-service program through the later years in a teaching career. Our initial interest in this area was guided by our observation that many of our pre-service teachers held beliefs conducive to reform-based practices, yet during their first years in the classroom few reform-based practices or beliefs were evident. This was compounded by our experience in professional development programs for experienced teachers, which revealed that these teachers held and formed reform-based beliefs as they learned new methods of instruction and assessment. We hoped that by understanding the change in beliefs of a teacher, we could design programs for teachers that would support their development towards constructivist or reform-based ideologies. In this process, we began documenting the beliefs of teachers and developed the Teacher Beliefs Interview (TBI), which helped us understand how teachers were impacted by their teacher education experiences. This paper reports the process of developing the TBI and our current use of the TBI with beginning secondary science teachers, along with the results of our initial studies.

Related Literature

Descriptions of Beliefs in Educational Research

Educational researchers have described beliefs in different ways. Some researchers lump beliefs and attitudes together and give little attention to the unique attributes of each (e.g., Garmon, 2004). Other researchers interchange terms such as theories and philosophies with beliefs, acknowledging that these are personal constructions (e.g., Simmons et al., 1999). Still other researchers equate beliefs and knowledge, as both guide actions and inform an individual's decision making process (e.g., Kagan, 1990). In some instances, the assumptions underlying the varied terminology are detailed, and in other instances there is little discussion. Given the disparity, those who study beliefs need to clearly articulate the nature of the beliefs that are being examined.

Those who have written about beliefs acknowledge their unique composition and cognitive affiliation (e.g., Fang, 1996; Fishbein & Ajzen, 1975; Jones & Carter, 2007; Nespor, 1987; Pajares, 1992; Richardson, 1996; Rokeach, 1986). For these researchers, beliefs are clearly personal constructions, entities that belong to an individual. Yet additional descriptions reveal varied notions of beliefs. For instance, Fishbein and Ajzen (1975) suggest that

> "a belief links an object to some attribute…the object of a belief may be a person, a group of people, an institution, a behavior, a policy, an event, etc. and the

> associated attribute may be an object, trail property, quality, characteristic, outcome or event (p. 12)."

Nespor (1987), on the other hand, describes beliefs as episodic, highly personalized, and containing affective and evaluative components. Descriptions similar to those offered by Nespor (1987), which are characterizations about beliefs, are more widely acknowledged by educational researchers.

The discrete and multidimensional nature of beliefs is less problematic to those who study beliefs. Schommer (1993), like other researchers, has found that individuals can hold beliefs that are independent of one another and have a varied impact on actions or cognitive processes. This means that individuals can hold beliefs that are in conflict with one another, that have different representations, and that are both generalizable and context specific. This variability is often associated with the core and peripheral nature of beliefs (Brownlee, Boulton-Lewis, & Purdie, 2002; Rokeach, 1986), and affects one's cognitive schema in different ways. Core beliefs are often more connected within a system and are more coherent with one another, while peripheral beliefs are not as extensively connected to other beliefs in the system and may be in conflict with one another. Moreover, beliefs that are more central and more connected can be more resistant to change (Kagan, 1992). Adding to this, the position of a belief and its construction may result in the belief acting as a filter. As a result, more compatible experiences or information may be processed within a belief set, while incompatible experiences may be held to the periphery, filtered, or rejected (Nespor, 1987).

Capturing Teacher Beliefs

Beliefs are critical when it comes to understanding a teacher's practice. Ernest (1989), for example, found that two mathematics teachers with similar knowledge taught in different ways. He suggested from his study that an understanding of beliefs was more useful in predicting teachers' classroom decisions. Fang (1996), in a review of research on beliefs and practices, synthesized the research on the relationship between beliefs and practice and suggested that beliefs tend to affect behaviors. He also noted that factors outside of the classroom and teacher can also impact practice. Fang's findings are consistent with other educational researchers, who generally agree that beliefs are connected to actions in the classroom (e.g., Guskey, 1986; Hashweh, 1996; Kang & Wallace, 2004). However, these and other authors indicate that pressing issues pertaining to beliefs and practice still exist, such as the nature of the interaction between beliefs and practices. Some researchers consider beliefs and practices to be interactive, while others conclude that beliefs must change before practices can change. In either case, it is important to understand the teaching beliefs of teachers, in light of the compelling evidence that beliefs influence practice.

Researchers often explore the beliefs teachers hold at different times in their careers. Richardson (1996), in her review article, concluded that professional development opportunities for experienced teachers were likely to have the greatest impact on beliefs. Such opportunities can influence experienced teachers to expand and modify their existing beliefs. Richardson also concluded that pre-service experiences were ultimately too short in duration to have any lasting impact on beliefs. Luft (2001), in a study of experienced and beginning teachers, found that beginning teachers were more likely to change their beliefs when learning about inquiry but less likely to change their practices, while experienced teachers were less likely to change their beliefs and more likely to change their practices. The degree that beliefs of new teachers were able to change was attributed to the formidable nature of the beliefs. The experienced teachers, on the other hand, had beliefs about teaching that were established and consistent with the goals of the professional development program, which in turn influenced their decision to even participate in the program. Clearly, the beliefs of teachers are subject to varying degrees of change throughout one's career. These changes are indicative of the types of beliefs examined and the central or peripheral nature of the beliefs.

More recently, educational researchers have focused on epistemological beliefs. These beliefs concern teachers' views about nature and the acquisition of knowledge (e.g., Bendixen, Dunkle, & Schraw, 1994; Hofer & Pintrich, 1997). Such beliefs are intertwined with teachers' beliefs about learning, understanding, or student knowledge; as how a teacher conceptualizes knowledge impacts their teaching beliefs (Brownlee, Boulton-Lewis, & Purdie, 2002). In order to capture and describe these types of beliefs, the research process must allow teachers to describe and elaborate on their beliefs about knowledge and teaching. Interviews, ranking tasks, and constructed response formats have been used to capture teachers' epistemological beliefs; these methods allow teachers to thoroughly discuss the conceptualization of their beliefs (Ambrose, Clement, Philipp, & Chauvat, 2004; Munby, 1982).

Methods

Background

In order to understand, or elicit the beliefs of teachers, it is important to make beliefs "visible." Fang (1996) and Munby (1982) noted the shortcomings of written self-report responses that may reflect what should be done rather than what is actually done in practice. Pajares (1992) and Richardson (1996) stated that multiple forms of data were needed in order to understand teacher beliefs, although collecting this type of data can be difficult for even the most seasoned researcher. The semi-structured interview poses an alternative to written responses and multiple data sources. This format allows the researcher to access the thinking of a teacher and to determine aspects of the teacher's thinking that cannot be captured through observation or other modes of data collection (Patton, 1980).

In our research, the qualitative methodology of interviewing was used to develop the TBI. Semi-structured interview questions were used to elicit the beliefs of each teacher, allowing the interviewer to probe the thoughts of the teacher in order to understand his or her beliefs. Berg (1998) and Patton (1990) guided the development of our identified interview questions. Once the interviews were collected, they were inductively analyzed in order to understand how certain perspectives were manifested within the teacher. Patton (1990) refers to this as an orientational methodology.

Process

After reviewing the research on beliefs and consulting with experts who study teacher beliefs, we developed eight questions for the TBI. The initial questions were drawn from Richardson and Simmons (1994) as well as our own protocol (Roehrig, 2002). Using the initial questions, four researchers then conducted interviews with ten beginning secondary science teachers. The responses were collected and used to revise the interview process. We aimed to produce standardized, open-ended questions that were clearly stated to the teachers and that explored their beliefs (Patton, 1990). Our initial revisions included shortening the questions, revising the wording in order to capture the beliefs of teachers, and removing one question from our interview sequence. Once again, we reviewed the questions and answers of teachers to determine if we were capturing beliefs. Our review specifically sought to determine if the questions elicited teacher responses that were highly personalized, often constructed in episodic ways, and contained affective and evaluative components (see Nespor, 1987; Pajares, 1992). Moreover, we examined the questions to determine the presence of an object and an attribute, and an orientation towards knowledge (see Bendixen, Dunkle, & Schraw, 1994; Fishbein & Ajzen, 1975). Through an iterative process of revision and reflection, eight questions were developed.

During the next phase of the development of the TBI, three researchers inductively analyzed 75 transcribed interviews of beginning and experienced secondary science teachers in one state. Through this process the major concepts, themes, or categories present within each question were identified. Categories that emerged from the transcripts of the interviews resulted from the constant comparative method of data analysis (Glaser & Strauss, 1967). Each question and its corresponding categories were then placed in a clustered summary display (Miles & Huberman, 1994), which later gave rise to a graphical representation of the question.

The emergent categories for the questions were traditional, instructive, transitional, responsive and reform-based. Traditional and instructive responses represent teacher-centered beliefs, while responsive and reform-based responses represent student-centered beliefs. Transitional responses reflect a view of students that focuses on primarily behaviorist and affective attributes of students, not always the cognitive involvement. A further elaboration of the epistemological underpinning resulted in three areas of classification, which are similar to those found in Ernest (1989). Specifically, traditional responses reveal science as based on facts, rules and methods that are transferable; transitional responses represent science as a body of certain knowledge; while reform-based responses support science as a dynamic field that is subject to revision. Table 1 summarizes these categories and the epistemological underpinnings.

The final phase of development of the TBI entailed conducting interviews with pre-service, induction, and experienced science teachers in three different states. Over 40 interviews were conducted, and in some instances multiple interviews were conducted with participants during a two-year period. The interviews were analyzed by two different researchers, with the answers compared to the current TBI. After the coding of these interviews, three researchers met to revise the TBI to better represent the beliefs of the expanded group of teachers. This final meeting resulted in the deletion of one question and the formal connection of the questions to different epistemological domains in science teaching. While these categories are not comprehensive, they are broad enough to depict the epistemological beliefs of science teachers. The final TBI questions are presented below, while the questions with selected responses can be found at the end of this paper.

1. How do you maximize student learning in your classroom? (learning)
2. How do you describe your role as a teacher? (knowledge)
3. How do you know when your students understand? (learning)
4. In the school setting, how do you decide what to teach and what not to teach? (knowledge)
5. How do you decide when to move on to a new topic in your classroom? (knowledge)
6. How do your students learn science best? (learning)
7. How do you know when learning is occurring in your classroom? (learning)

Reliability & Validity

In order determine the generalizability of the TBI to other discipline teachers, we used the TBI with pre-service mathematics teachers. At first, one might think that teachers would provide similar answers across subjects. However, this was not the case. In their answers, teachers clearly drew upon their content knowledge and their understanding of the nature of knowledge construction in mathematics. The answers provided by mathematics teachers differed from those of the science teachers, thus supporting the reliability of the questions. In addition to questioning other groups of teachers, we reviewed the responses of the teachers and our own questioning process. The language and explanations of the interviewed teachers indicated that we had created a non-threatening atmosphere in which genuine responses were possible. Our own verbal cues, along with the responses from the teachers, give us confidence in the reliability of the responses (Fowler, 1993). Finally, the Cronbach alpha coefficient for the internal consistencies survey was calculated at 0.70.

Determining the validity of this process entailed multiple reviews of the interviews, as well as comparisons with data from other interviews that were collected in the course of the study. In each instance, we tried to identify alternative constructions and to determine if they were truly different, or if they aligned with our categorizations. Throughout our process of reviewing interviews and examining the responses, we found that our depictions held up, thus the validity of our process was supported (Patton, 1990).

Limitations

Before discussing the results of the TBI and our process of documenting different groups of teachers, we need to acknowledge the limitations. First, the very nature of identifying beliefs is difficult. In trying to capture the beliefs of teachers, we may have inadvertently captured behavioral intentions, which represent a person's intention to perform various behaviors (Fishbein & Ajzen, 1975). However, we were conscious of this problem and sought to capture beliefs by having teachers describe the epistemological side of the event. Second, even though we tried to adhere to methods that address issues of reliability and validity, these are areas of concern with just one method of data collection. In an effort to address this issue we involved multiple researchers, examined the data different times, expanded our data collection to multiple interviews and different geographic areas, and worked with our subjects to establish rapport in order to enhance our access to their thinking (Patton, 1990). Although there are limitations associated with this process, we have confidence that our generated representations reveal the beliefs of science teachers.

Using the TBI

We are currently using the TBI to track changes in the beliefs of beginning secondary science teachers in different induction programs, and pre-service teachers who are participating in a teacher preparation program that begins during their freshman year. Both of these studies are tracking teachers over a period of time and as a result the teachers are participating in belief interviews over several years.

In preparing to talk to a teacher about his/her beliefs, we often begin our scheduled session by asking the teacher to talk about his or her current experiences as a new teacher or as a student in a teacher preparation program. In our experience, this allows the teacher to talk about his or her experiences and develops a comfort level with the interviewer that allows for a deeper discussion of thinking later in the interview process. This beginning part of the interview usually lasts from 10 to 30 minutes and can result in teachers discussing student accomplishments, well-developed lessons, or experiences that are conducive to their growth as a teacher. Following this section of the interview, we begin the interview about beliefs. As we interview the teacher, we ask for examples and rich details that highlight the epistemological side of the question. Additionally, we do not have the TBI maps with us, as this would guide our questioning towards areas in the maps. When we complete the interview, we always ask the teacher if there are additional comments he or she would like to make about being a science teacher. This often results in an additional 5 to 15 minutes of discussion. The entire beliefs interview process usually lasts from 20 to 30 minutes, and all of the interviews are digitally audio-taped. The duration of the interview depends on the comfort of the teacher with the interviewer. It should also be noted that most teachers are not interviewed by the same person, as this helps to ensure we have the best representation of the teacher's thinking over time.

Once the interviews are conducted, they are transcribed and coded or they are coded directly from the digital tape recording. Each interview is scored independently by two researchers. During the coding process, notes are made by each researcher on a separate piece of paper that summarizes the beliefs of the teacher. The last coder is responsible for looking at the level of agreement between both coders. If there are areas which are not in agreement, either both researchers can visit the question(s) that do not agree or a third researcher can listen to data, examine the prior codings, and make a decision. Once the codes are determined, the responses are merged to depict a beliefs profile that represents a teacher's beliefs over time (see Luft, 2001 for a more comprehensive report of the process). Table 2 is an example beliefs profile.

The resulting beginning and ending categories are then compared to each other to produce a summary of the teacher's beliefs. This is done to determine the degree of change or to establish a predominant teaching philosophy of the teacher. When we found variations between pre- and post-interviews, we noted beginning teachers' beliefs about teaching as shifting, alternating, or not changing. A shift in beliefs about teaching results when three or more of the answers in the post-interview move one category or more to a student-centered or teacher-centered ideology, and/or in expanded answers that reveal new understandings. This type of change depicts beliefs that are becoming similar in orientation. An alternation of beliefs about teaching occurs when three or more of the answers move to teacher-centered or student-centered categories, instead of all responses moving in one direction, and/or when responses indicate new or refined ways of explaining teaching that emphasize teacher or student-centered approaches. Alternating beliefs are not stable and have the potential to move again. It should be added that the modification or change in at least three answers tends to be the threshold indicating important shifts in beliefs. That is, teachers who changed at least three categories were in the midst of constructing new or modifying existing belief systems. No change in beliefs occurs when only one or two participant responses shift categories, and/or when no expanded discussion occurs. Generally, beliefs with this degree of change are relatively stable.

An Example

An Interview with a Teacher

The post-interview of Sandy (pseudonym), a first-year secondary science teacher, was conducted in the office of a researcher at the university. She arrived early and was excited to discuss the completion of her first year as a middle school science teacher. Her school consisted primarily of Hispanic students; most of the children learned English as their second language and participated in a district program that provided meals for free or at a reduced cost. Sandy wanted to teach in this setting, though it was not always an easy place to work. Once Sandy was comfortable and the basics had been covered, the beliefs portion of the interview began.

In response to the first question about maximizing student learning in the classroom, Sandy paused for a bit, then said, "By using lots of different types of instruction. By giving the kids multiple opportunities to demonstrate their understanding. Doing projects that they want to learn about." Between each sentence she also paused, as if to emphasize the points she made.

The interviewer followed up by asking if there were other things that she did to maximize student learning. The question was restated to allow Sandy to think about the question and perhaps formulate a more in-depth answer. Sandy contemplated the question. She eventually replied that "In the classroom, I try to give the students lots of time to talk about their learning and their thinking. I try to provide a positive atmosphere in which the kids are comfortable to learn. For example, when we did our last unit, which was on genetics, the kids had opportunities to talk to one another and think of questions that were relevant to the lab. The activity was good, as the kids are a generation of CSI [Crime Scene Investigation] watchers and they naturally have questions about the genetics. This lab really grabbed them and allowed them to use their research skills." Sandy continued to talk about the kids and how she wanted them to raise questions, but later in the interview she shared that she likes having answers for students when they ask questions.

When Sandy had spoken enough about this question (the point at which no new information was added to the conversation), the interviewer asked her about her role as a teacher. Again Sandy was silent for a bit, then answered the question. She started by explaining that she did not want to “be a being of knowledge that gives knowledge to the students. I want to provide them opportunities to ask questions and to model how they can learn on their own. I really want them to be independent learners. I really try to steer clear of lecturing. I always try to set up an activity and let them go at it. If I am successful, I have used real life examples and they are backing their conclusions up with fact.”

Still not clear that an answer was evident, the interviewer restated the question “How does this represent your role as a teacher?” Sandy responded that “I give them an idea or a venue and they get to run this. They get to research it and develop their ideas and show their personality in the assignment. When they do this, they get the chance to learn on this own. Hopefully this knowledge will stick a bit longer. “

After Sandy’s pause, the interviewer quickly asked “What did you do with the kids while they were doing this?”

Sandy responded without a break “I talk to the kids and ask them questions about the assignment. Hopefully, if I ask a question, then they can find the information. You know, they know about the different search engines, but they really don’t know how to determine if it’s good information they are getting. If they need to find information, they can go to the internet, but they need to know if the information is useful. It’s important that I help them understand if the information that they have is good information.”

These two questions, presented in an abbreviated fashion, begin to reveal an orientation that Sandy has towards teaching science. In her first question, Sandy talks about examples that show involvement of the student in the classroom. She is intent on providing good experiences to the students, but has not yet come to develop an interaction between the knowledge students are creating and the knowledge of the students. Her response to the question was coded as *Transitional* (see Table 1).

In her second question, Sandy does not give an easy answer to the question. The answer that she gives reveals that she is intent on giving her students opportunities to learn, which is similar to the response she gave in her first question. Even with additional questions, it is clear that Sandy wants her students to have experiences and that she will help direct these experiences. Her position towards the students and the content result in her being coded as *Instructional* (see Table 1) for this question.

The responses provided by Sandy are typical of most new science teachers. She is building her beliefs about teaching the content, and with more classroom experience these beliefs will certainly change over time. Pivotal in her change will be the type of discussions and experiences she has with colleagues in her first years of teaching.

Looking at a Group of Teachers

We recently completed an analysis of data on a group of 35 first-year secondary science teachers. These teachers were grouped according to the induction program in which they participated: general induction, e-mentoring, science-focused, or alternative certification programs. Each teacher participated in a pre and post-interview, which was evaluated as described earlier in this paper. While a complete discussion of the research and the complete analysis of the pilot year results are in review (see Luft, Fletcher, Kern, Roehrig, & Brown, in review), it is worth sharing the beliefs data to show the analysis of this data over a year. As our goal in this study was to explore the change in teachers over the year, we first coded the data and created a table showing the averages and standard deviations (see Table 3). When an F-test was conducted to determine significance in change between groups, we found no statistically significant difference between the programs in terms of change in teachers' beliefs ($F(3, 20) = .59$, $p = .63$).

While the data were not statistically significant for the pilot year, some trends are evident. For instance, we see that teachers tend to have instructional beliefs (around 14). These beliefs tend to shift towards more traditional orientations for those teachers in general programs and in alternative certification programs, while teachers in science-focused and e-mentoring programs (which are also science focused) tend to move towards transitional orientations. Again, these shifts are not significant, but they are evident. In the formal study, we are exploring (among other areas) each belief item, as we have a large enough pool of teachers (120 teachers).

This data is interesting for science teacher educators involved in beliefs research, as it shows that beginning science teachers have beliefs that are aligned with traditional epistemologies. Most science educators would hope that teachers who graduated from their programs would have transitional or instructive beliefs about teaching science. Moreover, the data shows that the beliefs of these teachers did change slightly over the year. These two findings suggest that teachers may have beliefs that are resistant to change and that they may not have been impacted by the pre-service program, or that teachers are forming peripheral beliefs that are slow to change. In the years ahead, we will be exploring these hypotheses, along with others.

Discussion

We consider beliefs to be propositions that individuals think are true. Since these beliefs are based on personal judgment and evaluation, they can be non-evidential; in this sense we concur with Richardson (1996). In terms of science teaching, we consider beliefs to be core and peripheral, as do Brownlee, Boulton-Lewis, and Purdie (2002), and epistemologically oriented, as described by Bendixen, Dunkle, and Schraw (1994). All teachers have personally constructed beliefs about teaching. As teachers engage in their field of instruction, these beliefs expand in their epistemological orientation. Capturing the beliefs of teachers is important to those in science teacher education--ultimately, beliefs reveal how teachers view knowledge and learning, and suggest how they may enact their classroom practice. As peripheral beliefs are forming, it is critical that they be monitored during formative periods such as the first years of teaching or during intensive professional development activities.

While our work has focused on the beliefs of beginning secondary science teachers, we have also worked with pre-service secondary science teachers and experienced secondary science teachers in an effort to understand their beliefs about science teaching. Our studies have revealed, among other findings, that the beliefs of science teachers can change or be modified and that they are likely to do so within certain parameters. For example, pre-service science teachers who display tendencies towards student-centered activities and instruction can develop more responsive ideologies with specialized support. Correspondingly, they also can move towards more traditional practices in the absence of adequate support. With these types of changes, we concur with Yerrick, Parke and Nugent (1997) that beliefs can be modified, as such beliefs tend to be evolving. In addition, we agree with Fang (1996) that external factors--such as professional development or induction programs--can impact beliefs. Generally, these types of change/modifications represent the tentative nature of beliefs in beginning teachers, supporting the view that beliefs can be newly formed and peripheral (Brownlee, Boulton-Lewis, & Purdie, 2002; Rokeach, 1986).

Like Brownlee, Boulton-Lewis and Purdie (2002) and Wallace and Kang (2004), we found that nascent beliefs are often intertwined. We also found that teachers do not compartmentalize different beliefs. The interplay between beliefs demonstrates that they are nested within each other and are not always discrete entities. For instance, as teachers discuss the learning of students they often make connections to the knowledge of students. These types of connections are important, as they contribute to a more holistic view of teaching. One constraint associated with the connected nature of beliefs, is collecting enough information to analyze the nature of the different beliefs. In realizing this constraint, we make sure that we have adequate information to determine the beliefs of a teacher, and often draw upon answers given in different parts of the interview to understand the orientation of one answer. For example, teachers may talk at length about their role as a teacher, but later in the interview they may give an example that highlights this position. To negotiate the nestedness of beliefs, one researcher is responsible for coding all of the pre- or post-interview questions of a science teacher, as opposed to just coding the first, second, or third question.

In addition to these findings, we have reported on other aspects of beliefs over the years. These findings can be found in several of our papers and include the following (see; Luft, 2001; Luft, Fletcher, Fortney, 2005; Luft, Lee, Fletcher, & Roehrig, in press; Luft, Roehrig, & Patterson, 2003; Roehrig & Luft, 2004a; Roehrig & Luft, 2004b; Roehrig & Luft, 2006):

- Science teachers with transitional beliefs are more likely to move towards traditional or reform-based dispositions;
- Beginning secondary science teachers have primarily instructive and transitional beliefs;
- Beginning secondary science teachers' beliefs are more likely to change than those of their experienced peers;
- The beliefs of beginning secondary science teachers as depicted in this interview process (traditional, instructive, transitional, responsive, reform-based), tend to correspond with traditional (traditional or instructive), guided (transitional) or inquiry-based (responsive or reform-based) practices;
- The beliefs of beginning secondary science teachers can be impacted by subject-specific induction programs;
- Aspects of teacher education programs can impact the beliefs of science teachers differently, with some courses fostering more traditional or reform-based beliefs.

As we explored the beliefs of teachers, we elected to engage in an interview process. This process does give us access to the beliefs of teachers, which are the deep-seated views that direct practice. While some have argued that beliefs data without observational data or multiple data sources is problematic (Pajares, 1992; Richardson, 1996), we feel otherwise. In fact, from our experience, interviews can provide access to the thinking of teachers. Moreover, the interview process allows the teacher to reveal the complexity of the belief system. Interviews, in our experience, do transcend the shortcomings of written responses that have been described by other researchers (Fang, 1996; Munby, 1982). Collecting observational data may be important in order to determine the translation of beliefs into practice, but conducting both to understand one event may confound our understanding of the nature of the beliefs of teachers. In our experience, detangling beliefs from practice is important, and interviews with teachers about practice and experiences do reveal the beliefs that teachers hold.

Conclusion

Understanding the beliefs of teachers is critical if those of us in science teacher education are going to develop programs that have a lasting impact on our teachers. As we begin to understand how the beliefs of science teachers form, we will be able to develop pre-service and professional development programs that are conducive to the optimal development of science teachers. Ultimately, this could result in a different configuration of course work and activities in a pre-service program or different processes that can be drawn upon during the professional development experience.

As we embark on beliefs research, we should be looking for new ways to reveal the beliefs of teachers. Our work with interviews suggests one viable option to the use of traditional paper and pencil tests to measure beliefs. Moreover, our work in this area suggests a method for looking at the emerging beliefs of the teacher. Along with the development of techniques to monitor the beliefs of teachers, science educators should also follow the beliefs of teachers throughout their development, as well as try to understand how the beliefs of teachers are connected to practice. Moreover, as beliefs are followed, consideration should be given to the types of experiences that impact the beliefs of teachers. In the coming years, this new information about teachers' beliefs will hold great interest for the science education research community.

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References

Ambrose, R., Clement, L., Philipp, R., & Chauvot, J. (2004). Assessing prospective elementary school teachers' beliefs about mathematics and mathematics learning: Rationale and development of a constructed-response-format beliefs survey. *School Science and Mathematics, 104*(2), 56-65.

Bendixen, L. D., Dunkle, M.E., & Schraw, G. (1994). Epistemological beliefs and reflective judgment. *Psychological Reports, 70,* 1595-1600.

Brownlee, J., Boulton-Lewis, G., & Purdie, N, (2002). Core beliefs about knowing and peripheral beliefs about learning: Developing a wholistic conceptualization of epistemological beliefs. *Australian Journal of Educational & Developmental Psychology, 2,* 1-16

Berg, B. L. (1998). *Qualitative research methods for social studies*. Needham Heights, MA: Allyn and Bacon.

Ernest, P. (1989). The knowledge, beliefs, and attitude of the mathematics teacher: A model. *Journal of Education for Teaching, 15,* 13-34.

Fang, Z. (1996). A review of research on teacher beliefs and practice. *Educational Research, 38,* 47-65.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Reading MA: Addison-Wesley Publishing.

Fowler, F. J. (1993). S*urvey research methods: Second edition*. Newbury Park, CA: Sage Publications.

Garmon, M. R. (2004). Changing preservice teachers' attitudes/beliefs about diversity. *Journal of Teacher Education, 55*, 201-213.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory*. Chicago: Aldine.

Guskey, T. R., (1986). Staff development and the process of teacher change. *Educational Researcher, (15),* 5-12.

Hashweh, M. Z. (1996) Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching, 33*, 47-64.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relationship to learning. *Review of Educational Research, 67,* 88-140.

Jones, M. G. & Carter, G. (2007). Science teacher attitudes and beliefs. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1067-1104). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Kagan, D. M. (1992). Professional growth among beginning and pre-service teachers. *Review of Educational Research*, 62, 129-169.

Kang, N., & Wallace, C. S. (2004). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education, 89*, 140-165.

Keys, C. W. & Bryan, L. A. (2001). Co-constructing inquiry-base science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching, 38*, 631-645.

Luft, J. A. (2001). Changing inquiry practice and beliefs? The impact of a one-year inquiry-based professional development program on secondary science teachers. *International Journal of Science Education, 23*, 517-534.

Luft, J. A., Fletcher, S., & Fortney, B. (2005) Recruitment programs: Promising or problematic strategy. *Science Educator, 14*, 41-48.

Luft, J. A., Lee, E., Fletcher, S., & Roehrig, G. (in press). Growing or wilting? Beginning biology teachers in a science-focused induction program. *American Biology Teacher*

Luft, J. A., Roehrig, G. H., & Patterson, N. C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*, 77-97.

Luft, J. A., Fletcher, S., Kern, A., Roehrig, G. H., .&. Brown, M (in review). Building a continuum of professional practice: An examination of beginning secondary science teachers.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis*. Thousand Oaks, CA: Sage.

Munby, H. (1982). The place of teachers' beliefs in research on teacher thinking and decision making, and an alternative methodology. *Instructional Science, 11*, 201-225.

Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19,* 317-328.

Pajares, M. F. (1992). Teachers' beliefs and education research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307-332.

Patton, M. Q. (1990). *Qualitative evaluation and research methods (2nd ed.).* Newbury Park, CA: Sage Publications.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *The handbook of research in teacher education* (2nd ed., pp. 102-119). New York: Macmillan.

Richardson, L. & Simmons, P. (1994) Self-Q research method and analysis, teacher pedagogical philosophy interview: Theoretical background and samples of data. (Athens, GA: Department of Science Education, University of Georgia).

Roehrig, G. H. (2002). Does one size fit all? The experiences of first year secondary science teachers. Unpublished doctoral dissertation from the University of Arizona.

Roehrig, G. H., & Luft, J. A. (2004a). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education*, 26, 3-24.

Roehrig, G. H., & Luft, J. A. (2004b). Inquiry teaching in high school chemistry classrooms: The role of knowledge and beliefs. *Journal of Chemical Education, 81*, 1510-1516.

Roehrig, G. H., & Luft, J. A. (2006). Does one size fit all? The experiences of beginning teachers from different teacher preparation programs during an induction program. *Journal of Research in Science Teaching*, 43, 963-985.

Rokeach. M. (1986). *Beliefs, attitudes, and values.* San Francisco: Jossey-Bass.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D., Richardson, L., Yager, R., Craven, J., Tillotson, J., Brunkhorst, H., Twiest, M., Hossain, K., Gallager, J., Duggan-Haas, D., Parker, J., Cajas, F., Alshannag, Q., McGlamery, S., Krockover, G., Adams, P., Spector, B., La Porta, T., James, B., Rearden, K., & Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*, 930-954.

Schommer, M .A. (1993). Comparisons of beliefs about the nature of knowledge and learning among postsecondary students. *Research in Higher Education, 34*, 355-370.

Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning, and science. *International Journal of Science Education, 24*, 771-783.

Wallace, C. S., & Kang, N. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching, 41*, 936-960.

Yerrick, R., Parke, H., & Nugent, J. (1997). Struggling to promote deeply rooted change: The 'filtering effect' of teachers' beliefs on understanding transformational views of teaching science. *Science Education, 81*, 137-159.

Table 1. TBI Category Description

Category	Example	View of Science
Traditional: Focus on information, transmission, structure, or sources.	I am an all knowing sage. My role is to deliver information.	Science as rule or fact.
Instructive: Focus on providing experiences, teacher-focus, or teacher decision.	I want to maintain a student focus to minimize disruptions. I want to provide students with experiences in laboratory science (no elaboration).	
Transitional: Focus on teacher/student relationships, subjective decisions, or affective response.	I want a good rapport with my students, so I do what they like in science. I am responsible to guide students in their development of understanding and process skills.	Science as consistent, connected and objective.
Responsive: Focus on collaboration, feedback, or knowledge development.	I want to set up my classroom so that students can take charge of their own learning.	Science as a dynamic structure in a social and cultural context.
Reform-based: Focus on mediating student knowledge or interactions.	My role is to provide students with experiences in science which allows me to understand their knowledge and how they are making sense of science. My instruction needs to be modified accordingly so that students understand key concepts in science.	

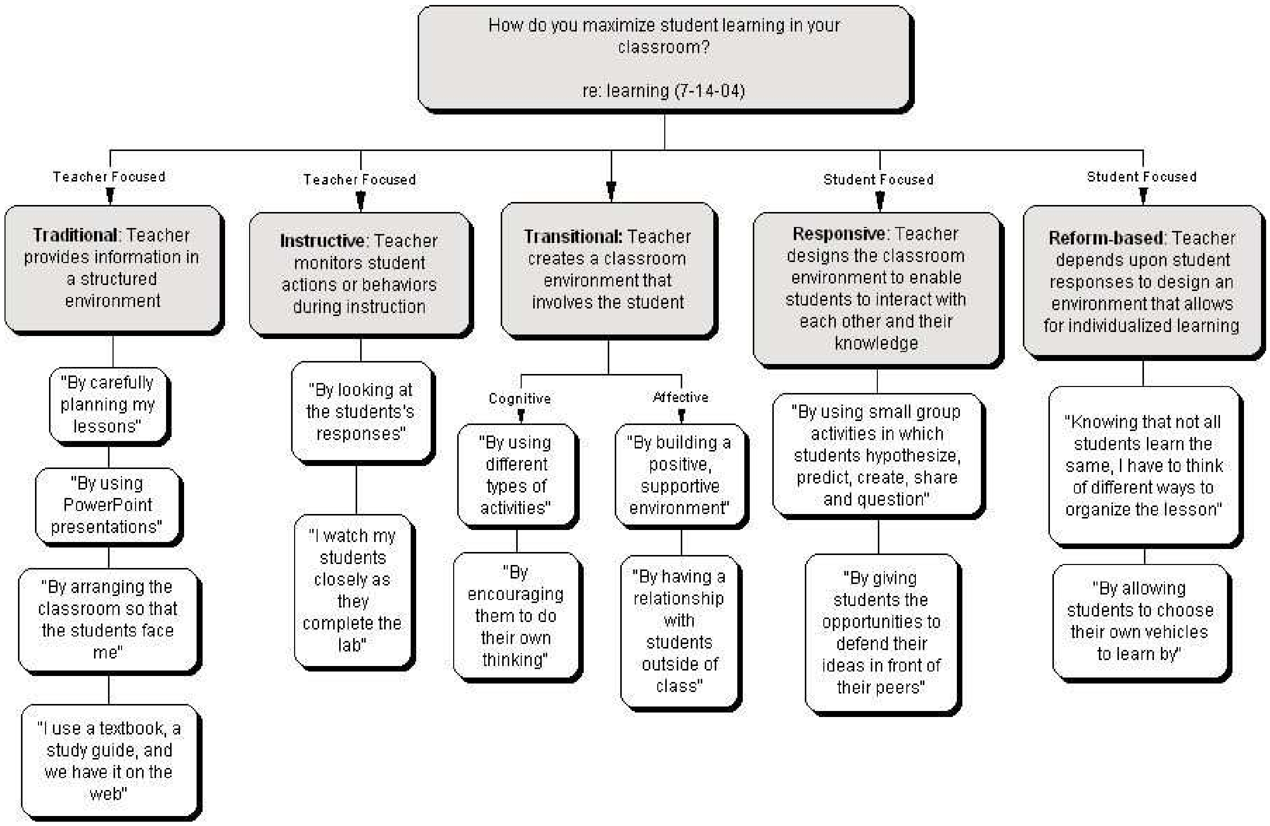
Table 2. Beliefs Profile of Teacher A.

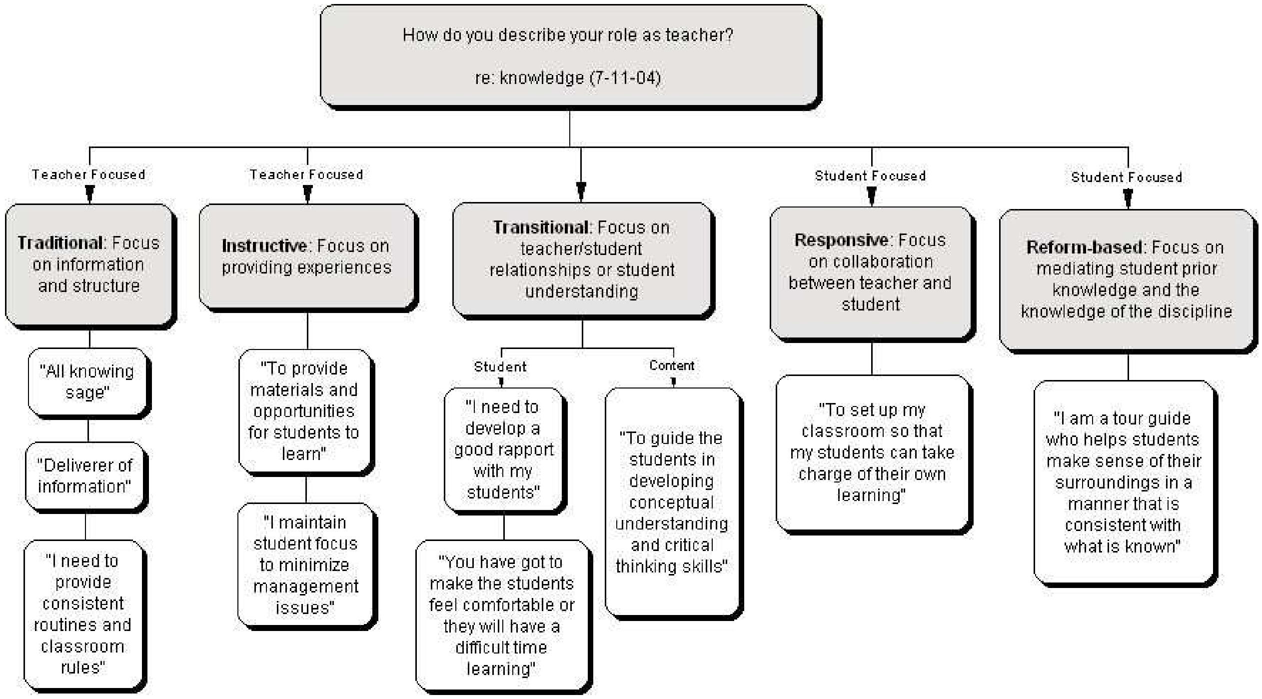
	Traditional	Instructive	Transitional	Responsive	Reform-based
Int. 1	****	**	*		
Int. 2	***	***	*		
Int. 3		***	****		
Int. 4		**	***	**	

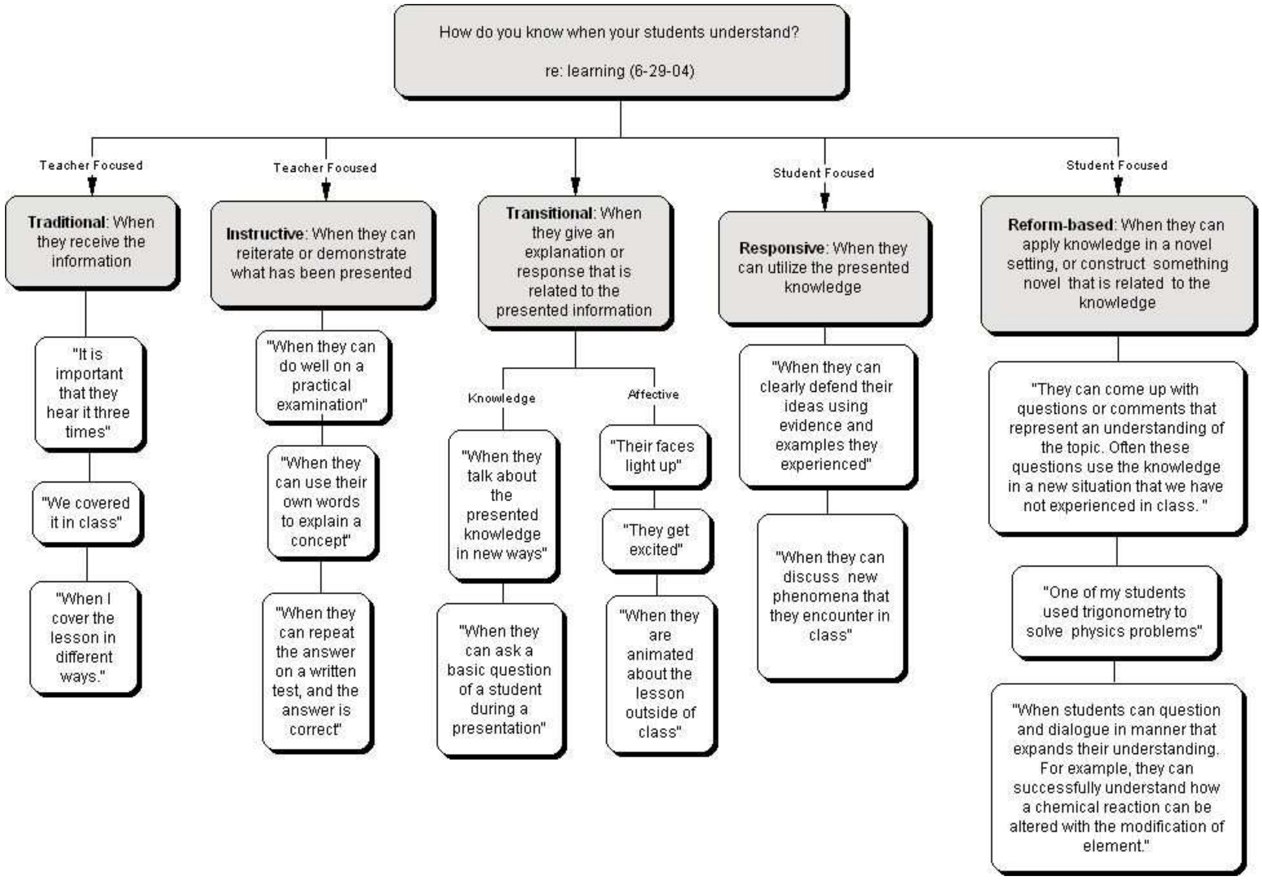
Table 3. Beliefs of Teachers in Different Induction Programs

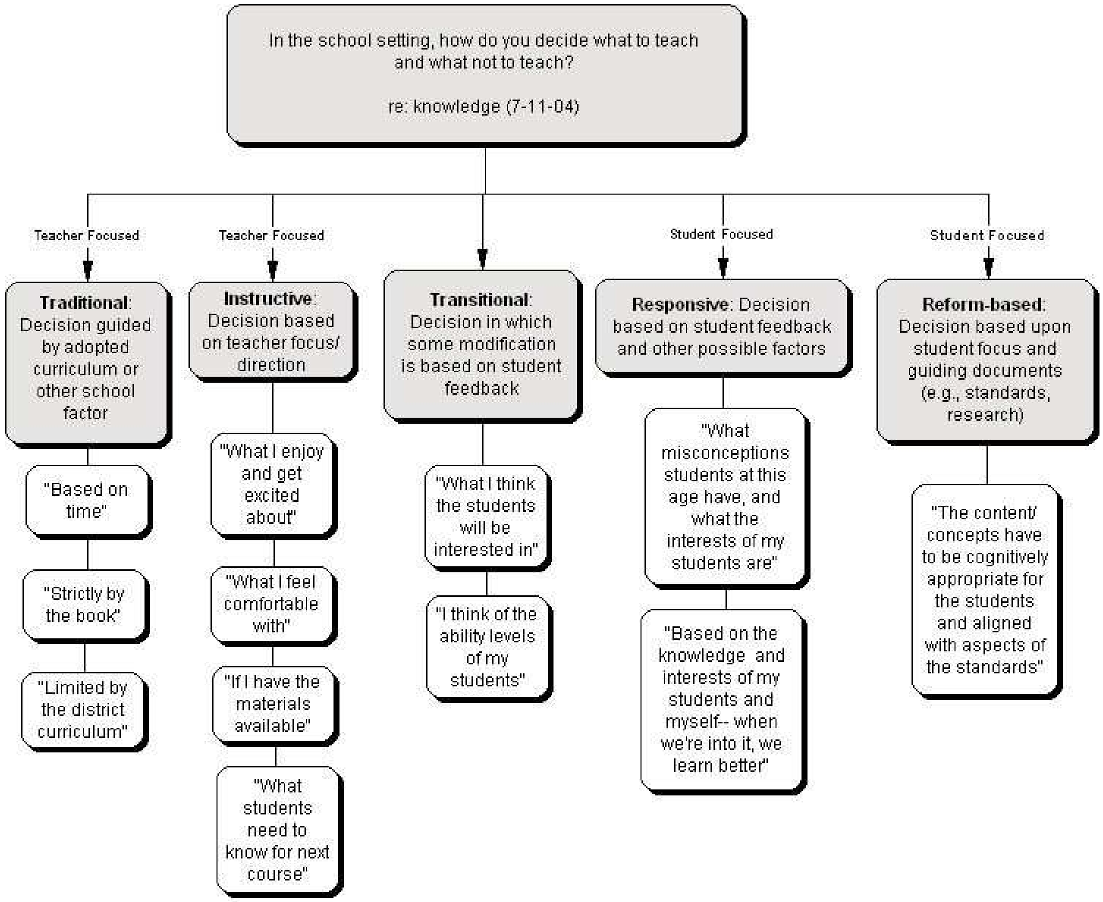
	General (10)	e-Mentoring (7)	Science specific (8)	Mentoring and certification (10)
Pre-beliefs	15.20 (3.96)	14.33 (1.63)	15.20 (2.68)	14.75 (4.40)
Post-beliefs	14.40 (2.88)	15.67 (2.42)	16.20 (4.21)	14.38 (2.13)

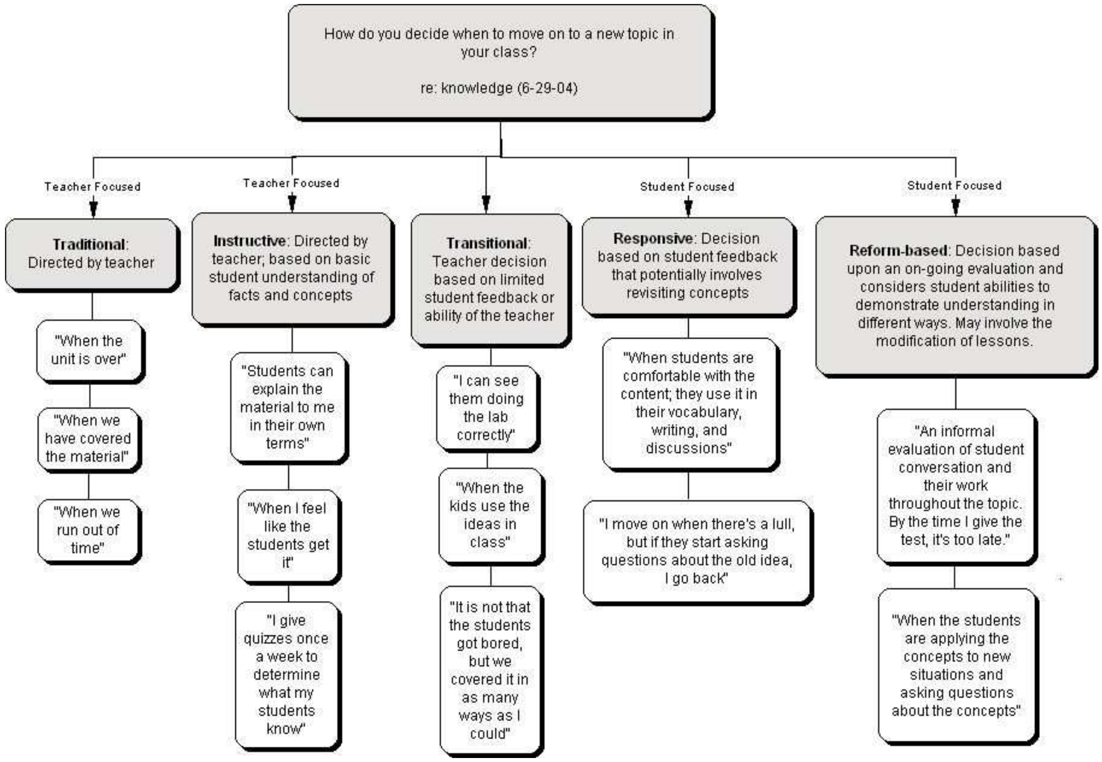
Figure 1. Beliefs Questions

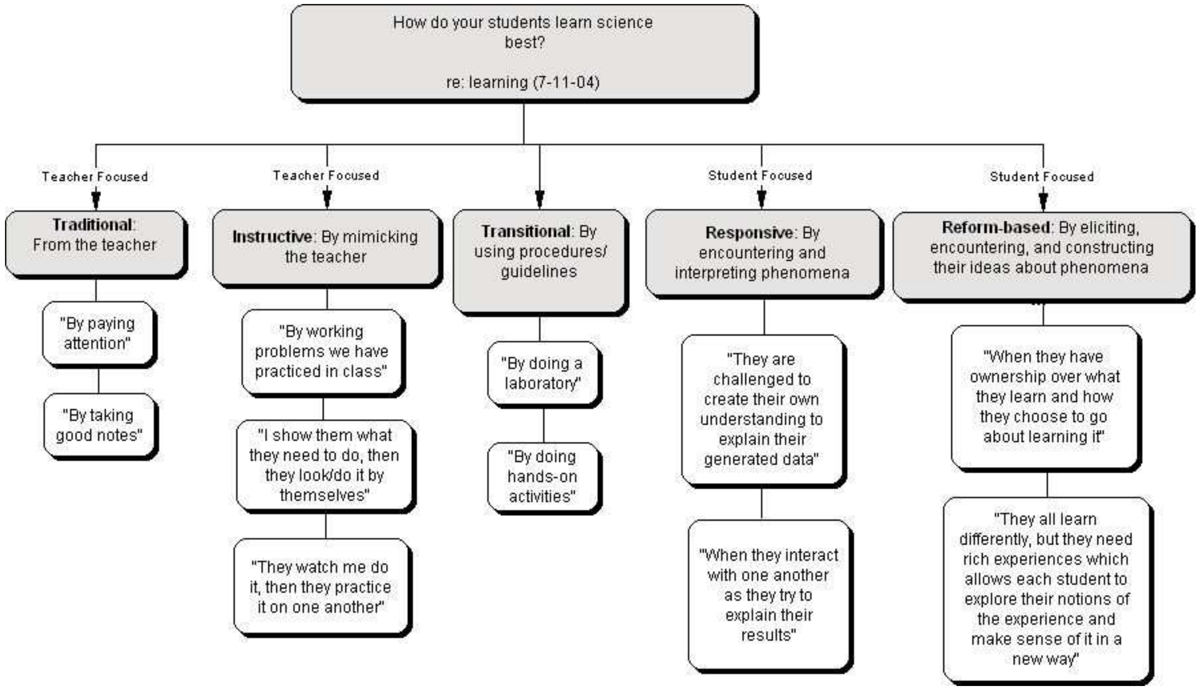


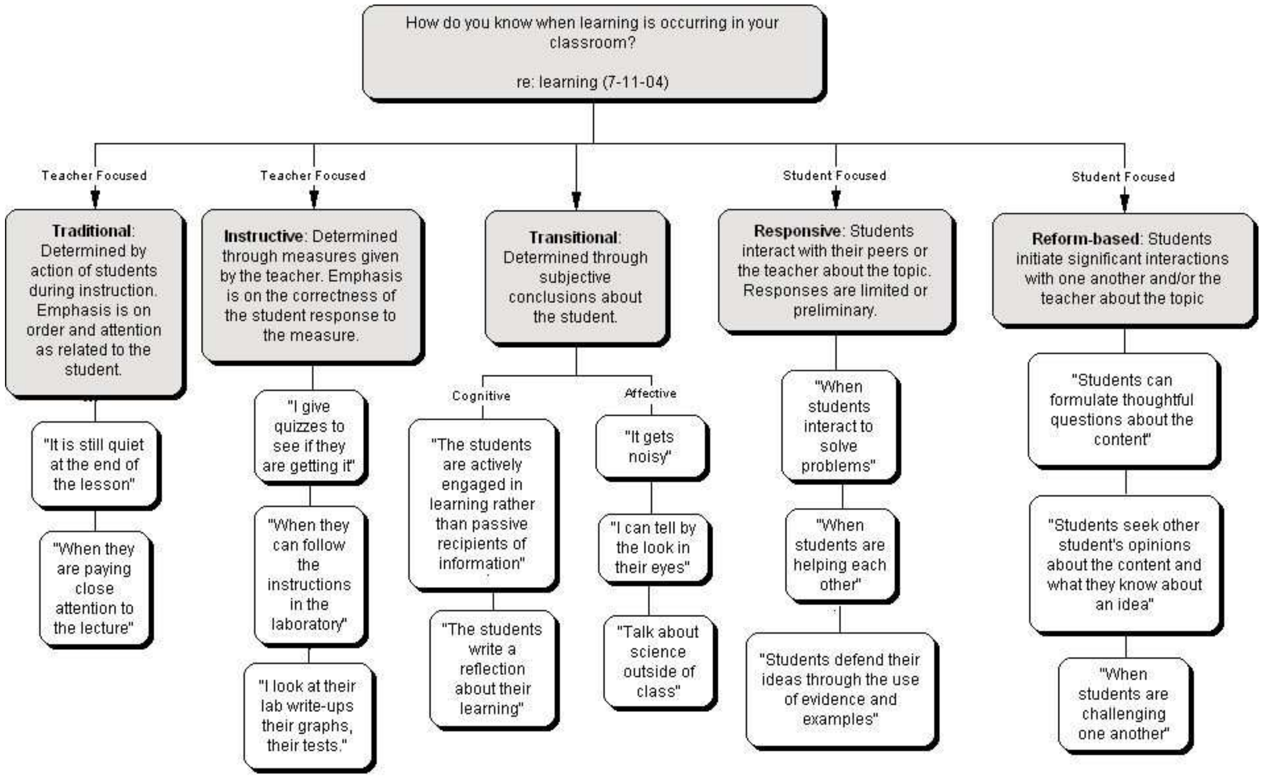

How do you describe your role as teacher?
re: knowledge (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Focus on information and structure
Instructive: Focus on providing experiences
Transitional: Focus on teacher/student relationships or student understanding
Responsive: Focus on collaboration between teacher and student
Reform-based: Focus on mediating student prior knowledge and the knowledge of the discipline
"All knowing sage"
"Deliverer of information"
"I need to provide consistent routines and classroom rules"
"To provide materials and opportunities for students to learn"
"I maintain student focus to minimize management issues"
Student
Content
"I need to develop a good rapport with my students"
"You have got to make the students feel comfortable or they will have a difficult time learning"
"To guide the students in developing conceptual understanding and critical thinking skills"
"To set up my classroom so that my students can take charge of their own learning"
"I am a tour guide who helps students make sense of their surroundings in a manner that is consistent with what is known"


How do you know when your students understand?
re: learning (6-29-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: When they receive the information
Instructive: When they can reiterate or demonstrate what has been presented
Transitional: When they give an explanation or response that is related to the presented information
Responsive: When they can utilize the presented knowledge
Reform-based: When they can apply knowledge in a novel setting, or construct something novel that is related to the knowledge
"It is important that they hear it three times"
"We covered it in class"
"When I cover the lesson in different ways."
"When they can do well on a practical examination"
"When they can use their own words to explain a concept"
"When they can repeat the answer on a written test, and the answer is correct"
Knowledge
Affective
"When they talk about the presented knowledge in new ways"
"When they can ask a basic question of a student during a presentation"
"Their faces light up"
"They get excited"
"When they are animated about the lesson outside of class"
"When they can clearly defend their ideas using evidence and examples they experienced"
"When they can discuss new phenomena that they encounter in class"
"They can come up with questions or comments that represent an understanding of the topic. Often these questions use the knowledge in a new situation that we have not experienced in class."
"One of my students used trigonometry to solve physics problems"
"When students can question and dialogue in manner that expands their understanding. For example, they can successfully understand how a chemical reaction can be altered with the modification of element."


In the school setting, how do you decide what to teach and what not to teach?
re: knowledge (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Decision guided by adopted curriculum or other school factor
"Based on time"
"Strictly by the book"
"Limited by the district curriculum"
Instructive: Decision based on teacher focus/ direction
"What I enjoy and get excited about"
"What I feel comfortable with"
"If I have the materials available"
"What students need to know for next course"
Transitional: Decision in which some modification is based on student feedback
"What I think the students will be interested in"
"I think of the ability levels of my students"
Responsive: Decision based on student feedback and other possible factors
"What misconceptions students at this age have, and what the interests of my students are"
"Based on the knowledge and interests of my students and myself-- when we're into it, we learn better"
Reform-based: Decision based upon student focus and guiding documents (e.g., standards, research)
"The content/ concepts have to be cognitively appropriate for the students and aligned with aspects of the standards"


How do you decide when to move on to a new topic in your class?
re: knowledge (6-29-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Directed by teacher
Instructive: Directed by teacher; based on basic student understanding of facts and concepts
Transitional: Teacher decision based on limited student feedback or ability of the teacher
Responsive: Decision based on student feedback that potentially involves revisiting concepts
Reform-based: Decision based upon an on-going evaluation and considers student abilities to demonstrate understanding in different ways. May involve the modification of lessons.
"When the unit is over"
"When we have covered the material"
"When we run out of time"
"Students can explain the material to me in their own terms"
"When I feel like the students get it"
"I give quizzes once a week to determine what my students know"
"I can see them doing the lab correctly"
"When the kids use the ideas in class"
"It is not that the students got bored, but we covered it in as many ways as I could"
"When students are comfortable with the content; they use it in their vocabulary, writing, and discussions"
"I move on when there's a lull, but if they start asking questions about the old idea, I go back"
"An informal evaluation of student conversation and their work throughout the topic. By the time I give the test, it's too late."
"When the students are applying the concepts to new situations and asking questions about the concepts"


How do your students learn science best?
re: learning (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: From the teacher
"By paying attention"
"By taking good notes"
Instructive: By mimicking the teacher
"By working problems we have practiced in class"
"I show them what they need to do, then they look/do it by themselves"
"They watch me do it, then they practice it on one another"
Transitional: By using procedures/ guidelines
"By doing a laboratory"
"By doing hands-on activities"
Responsive: By encountering and interpreting phenomena
"They are challenged to create their own understanding to explain their generated data"
"When they interact with one another as they try to explain their results"
Reform-based: By eliciting, encountering, and constructing their ideas about phenomena
"When they have ownership over what they learn and how they choose to go about learning it"
"They all learn differently, but they need rich experiences which allows each student to explore their notions of the experience and make sense of it in a new way"


How do you know when learning is occurring in your classroom?
re: learning (7-11-04)
Teacher Focused
Teacher Focused
Student Focused
Student Focused
Traditional: Determined by action of students during instruction. Emphasis is on order and attention as related to the student.
"It is still quiet at the end of the lesson"
"When they are paying close attention to the lecture"
Instructive: Determined through measures given by the teacher. Emphasis is on the correctness of the student response to the measure.
"I give quizzes to see if they are getting it"
"When they can follow the instructions in the laboratory"
"I look at their lab write-ups their graphs, their tests."
Transitional: Determined through subjective conclusions about the student.
Cognitive
Affective
"The students are actively engaged in learning rather than passive recipients of information"
"The students write a reflection about their learning"
"It gets noisy"
"I can tell by the look in their eyes"
"Talk about science outside of class"
Responsive: Students interact with their peers or the teacher about the topic. Responses are limited or preliminary.
"When students interact to solve problems"
"When students are helping each other"
"Students defend their ideas through the use of evidence and examples"
Reform-based: Students initiate significant interactions with one another and/or the teacher about the topic
"Students can formulate thoughtful questions about the content"
"Students seek other student's opinions about the content and what they know about an idea"
"When students are challenging one another"