

The Use of Constructivist Teaching Practices by Four New Secondary School Science Teachers: A Comparison of New Teachers and Experienced Constructivist Teachers

Abstract

The author examines the use of constructivist teaching practices by four new secondary school science teachers (NSTs) from a preparation program with a focus on constructivism. Data of the NSTs is compared to data of secondary school teachers from two different sources: (i) new teachers (NTs) from a broad-scale nationally-funded project involving ten different preparation programs across the USA and (ii) experienced teachers (ETs) who are nationally-recognized as effective constructivist teachers. All three sources of data were collected using the same instrument. As expected, it was found that the ETs outperformed NTs in general in their perceived use of all six sub-categories of constructivist teaching practices. However, it was also found that, in three sub-categories of constructivist teaching practices, the NSTs outperformed their counterparts from different programs. For these three sub-categories, the NSTs achieved at the level of "Student-Centered/Early Constructivist," as did the ETs. For the other three

sub-categories, the levels of achievements of the NSTs were similar to those of their counterparts. Qualitative data from videotapes and open-ended interviews further substantiate the finding that the NSTs are generally early constructivists, in both their practices and beliefs. These results support the idea that future educators should explicitly be taught the theory of constructivism and how to use it as a basis for teaching.

Introduction

A priority of the 21st century is real learning; that is, learning that includes the ability to think and to apply scientific knowledge for individual and social purposes, as opposed to merely memorizing and recalling facts. We live in what is known as a "knowledge society" in which information can be obtained with the click of a mouse. Hence, more and more jobs demand advanced skills that require people to be able to learn, reason, think creatively, make decisions, and solve problems (Bybee & Fuchs, 2006; Fensham, 2007). How does such learning take place?

Research emanating from the field of cognitive psychology has provided

a wealth of knowledge about the ways in which individuals construct their own understanding based on their personal experiences (Brooks & Brooks, 1993; Phillips, 1995; Saunders, 1992; Tobin, Tippins, & Gallard, 1994; von Glasersfeld, 1990; Yager, 1991, 2000). The term "constructivism" is most commonly used to refer to the theory that stems from this knowledge about learning. At the heart of constructivism is the idea that learning is neither passive nor a copying process. Rather, it is a process of active participation. Understanding is, at any given time, organized in the network of existing knowledge within the learner's mind (Schifter & Simon, 1990).

Constructivism is a cornerstone of current reforms in science education. Modern day science educators are echoing the ancient philosopher Plato: "...knowledge gained under compulsion obtains no hold on the mind" (Plato, 4 Century BCE. In Hamilton & Cairns, 1966, p.768). While constructivism does not prescribe explicit instructional strategies, the idea that all learners need to construct their own learning and understanding based on their past experiences provides the framework

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for what is termed “constructivist teaching practices”. What, then, is meant by “constructivist teaching practices”? Just as there is no complete consensus regarding what constructivism is, neither is there complete consensus pertaining to what constitutes constructivist teaching practices. The main data collecting instrument used in this report, the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser, and White, 1994) is just one measure of constructivist teaching practices. It ties in with what many science educators suggest are actions that characterize a “constructivist teacher” (Brooks & Brooks, 1993; Lutz, 1996; Yager et al., 2000). The constructivist teacher understands and uses constructivist principles by:

1. encouraging and accepting student autonomy, initiation, and leadership;
2. allowing student thinking to drive lessons and adapting content and instructional strategy based on student responses;
3. asking students to elaborate on their responses;
4. allowing wait time after posing questions;
5. encouraging students to interact, both with the teacher and with one another;
6. asking thoughtful, open-ended questions;
7. encouraging students to reflect on experiences and predict future outcomes;
8. asking students to articulate their theories before requiring them to present understanding of the concepts; and
9. looking for students’ alternative conceptions and

designing lessons to address misconceptions.

The effectiveness of a program is measured by the quality of teachers that it produces. Although the preparation of teachers is extremely complex, this researcher contends that all educators need to be explicitly taught the principles of constructivism and how to use them as a foundation for the development of teaching. This report focuses on the constructivist teaching practices of four new secondary school science teachers (NSTs) who have been educated in constructivist teaching.

Design and Procedure

This paper reports on parts of a larger study that investigated the constructivist behaviors of new secondary school science teachers (NSTs) from a teaching program that places a concentration on the theory of constructivism. This paper includes the perceptions of four NSTs, as well as their students’ perceptions, of the extent of their use of constructivist teaching practices during their second year of teaching. It also looks at two other related studies: a broad, large-scale study of new teachers (NTs) from 10 different programs across the USA and of a sample of experienced secondary school science teachers (ETs) who have received national recognition as effective constructivist teachers.

The three studies are related in that they all used the same survey instrument, the Constructivist Learning Environment Survey (CLES) (Taylor, Fraser & White 1994), to measure the use of constructivist teaching practices. CLES is frequently used because its validity has

been established. There are two versions of CLES. The teacher version measures a teacher’s perception of his/her own use of six sub-categories of constructivist teaching practices, and the student version measures student perceptions of these same factors.

Studies have indicated that student perceptions are better indicators of classroom reality than teacher perceptions (Salish I Research Project, 1997; Yutakom, 1997). The data on student perceptions of the use of constructivist teaching practices was provided from (i) a broad scale, nationally funded project that studied 175 new secondary school teachers (NTs) from 10 different preparation programs across the USA during their second year of teaching (Salish 1 Research Project, 1997) and (ii) a sample of 12 experienced (6 to 28 years of teaching) secondary school science teachers (ETs) who have been nationally recognized as successful constructivist teachers (Yutakom, 1997).

All mean scores were plotted onto a model that measures constructivist behavior expertise levels (refer to Table 1). This ‘Model of Constructivist Behavior Expertise Level’ (MCBEL) provides an additional reference for comparison by converting numerical values into ‘Expertise Levels’ (Lew, 2001). The model can be used across different instruments (including CLES) that measure constructivist behaviors using numerical scores following a Likert scale of 1 to 5, with a score of ‘1’ indicating the lowest level of constructivist teaching and a score of ‘5’ indicating the highest level of constructivist teaching (refer to Table 1).

Finally, the choice to compare new teachers’ second year of teaching for

Table 1: MCBEL - Defining Teacher Expertise based on Perceptions of Teachers' Use of Constructivist Practices

Perception	Teacher Centered		Transitional	Student Centered	
	Novice	Beginner	Transitional	Early Constructivist	Experienced Constructivist
Mean Scores	1.00 - 1.49	1.50 - 2.49	2.50 - 3.49	3.50 - 4.49	4.50 - 5.00

this report is partly due to data availability and partly to research findings that indicate that after teachers assume control of their own classrooms, there tends to be a drop in the level of their idealism from the level that had been attained during teacher preparatory programs and student teaching. Year two appears to be a crucial transition for new teachers adjusting to their positions. The effects of socialization factors and the pressure of full-time responsibilities tend to decrease by year 3 (Salish I Research Project, 1997).

This paper includes sample qualitative descriptions of the four NSTs' constructivist teaching practices and beliefs. Information was taken from videotaped lessons and open-ended interviews. As mentioned, the four NSTs are part of a larger longitudinal study that follows the participants from student teaching through their first three years of teaching. Besides yearly collection of perception data using the CLES surveys, yearly data were also collected from videotapes of actual classroom practices and from open-ended interviews. During student teaching, all NSTs were required to turn in a "Best Efforts" videotaped lesson to the program. Additionally, university mentors videotaped three consecutive days of teaching. The mentors also conducted and recorded yearly open-ended interviews for each teacher. These efforts were concentrated on the first three years of the new teachers' experience.

Here, it is important to stress that selection of the four NSTs for the original study was ultimately determined based on the information available, rather than by statistical specification. In the original longitudinal study of NSTs from the program, complete sets of data were obtained for these four NSTs. This includes all student CLES, all NST CLES, as well as videotaped lessons (N=37) and audiotape interviews (N=12). Sample description of observed constructivist practices and verbalized beliefs of the four NSTs were drawn from videotaped lessons and audiotapes of interviews. This will give the readers a deeper understanding of the six sub-categories of constructivist teaching practices as measured by the CLES, as well as substantiate the quantitative data. The original study is huge, and it is

Table 2: NSTs Expertise Levels in the Use of Constructivist Teaching Practice (Year 2 of Teaching)

Sub-Categories of Perceptions From CLES	Student Perceptions (N = 169)	Teacher Perceptions (N = 4)
Personal Relevance (PR)	Early Constructivist (mean 3.5)	Early Constructivist (mean = 3.6)
Scientific Uncertainty (SU)	Transitional (mean = 3.3)	Transitional (mean = 3.4)
Critical Voice (CV)	Early Constructivist (mean = 3.9)	Early Constructivist (mean = 3.5)
Shared Control (SC)	Beginner (mean = 2.9)	Beginner (mean = 2.4)
Student Negotiation (SN)	Transitional (mean = 3.4)	Transitional (mean = 3.2)
Attitude Towards Class (AT)	Early Constructivist (mean = 3.9)	Early Constructivist (mean = 3.6)

CLES – Constructivist Learning Environment Survey

NSTs – New Science Teachers from program with a focus on constructivism

not possible to provide all the rich qualitative details in this report. However, this researcher is directly involved in the program and considers the four NSTs in this report to be typical graduates of the program.

Findings

Table 2 shows the constructivist expertise levels of the four NSTs from the program with a concentration on constructivism during the end of their second year of teaching. It indicates that the extent of the teachers' use of constructivist teaching practices as perceived by the NSTs themselves is closely aligned with the perceptions of their students (N = 169). This lends support to the reliability of comparing this data (mean values and expertise levels) with the other two studies with larger sample sizes.

The findings from Table 2 can be summarized as follows:

1. Both the NSTs and their students perceived (year 2) NSTs as "Early Constructivist" in three sub-categories of constructivist teaching practices,

namely, providing personal relevance (PR), giving students a critical voice (CV), and building a positive attitude towards science learning (AT).

2. Both the NSTs and their students perceived (year 2) NSTs as “Transitional” in two sub-categories of constructivist teaching practices, namely, portraying the aspects of science as a fallible human activity (SU) and giving student negotiation opportunities (SN).
3. Both the NSTs and their students perceived (year 2) NSTs as “Beginners” in giving students shared control (SC) of the learning process (such as playing a role in decision making about their instruction).

Results comparing student perceptions of the extent of teacher use of six sub-categories of constructivist teaching practices as measured by CLES are tabulated in Table 3.

The findings from Table 3 can be summarized as follows:

1. The experienced, nationally recognized constructivist teachers (ETs) are perceived (by their students) to be more efficient in their use of all six sub-categories of constructivist teaching practices compared to new teachers in general (NTs).
2. The new science teachers (NSTs) from the program with a concentration on constructivism are perceived (by their students) to be more efficient in their use of constructivist teaching practices than the new teachers (NTs) from a combination of 10 different programs.
3. The NSTs from the constructivist program are perceived to match their more experienced counterparts (ETs) in three sub-categories of constructivist teaching practices, namely, providing personal relevance (PR), giving students a critical voice (CV), and building

a positive attitude towards science learning (AT).

4. Among the six sub-categories of constructivist teaching practices measured, giving students shared control (SC) of the learning process (such as playing a role in decision making about their instruction) appears to be the most challenging for all teachers, both new (NTs and NSTs) and experienced (ETs).

It is expected that teachers who are experienced and nationally recognized as constructivist teachers (ETs) would be perceived as using more constructivist teaching practices. However, this information is purely descriptive, and several important questions remain. Which factors might be responsible for the differences in student perceptions of the extent to which their new teachers (NSTs versus NTs) use constructivist teaching practices? Which factors might explain the reasons that the NSTs match ETs in three sub-categories of constructivist teaching practices? These questions will be discussed later.

Some qualitative examples of the constructivist teaching behaviors of the four NSTs are shared below. These sample qualitative data (from a total of 37 yearly videotaped lessons and 12 recorded open-ended interviews conducted throughout the span of the original study) support the findings that the four NSTs used constructivist teaching practices. The descriptions also serve to help readers better understand the sub-categories of constructivist teaching practices measured by the CLES. Amy (38 years), Bill (32 years), Caster (33 years), and Drake

Table 3: Comparing Expertise Levels of Student Perceptions of Their Teachers' Use of Constructivist Teaching Practices

Student Perceptions of:	Salish I (1997): 175 NTs (Year 2 Teaching)	Program with focus on Constructivism: 4 NSTs (Year 2 Teaching) N = 169	Yutakom (1997): 12 ETs (6 - 28 years teaching)
Personal Relevance (PR)	Transitional	Early Constructivist	Early Constructivist
Scientific Uncertainty (SU)	Transitional	Transitional	Early Constructivist
Critical Voice (CV)	Transitional	Early Constructivist	Early Constructivist
Shared Control (SC)	Beginner	Beginner	Transitional
Student Negotiation (SN)	Transitional	Transitional	Early Constructivist
Attitude Towards Class (AT)	Transitional	Early Constructivist	Early Constructivist

Early Constructivist (student-centered: mean scores from 3.50 to 4.49);

Transitional (between student-centered & teacher-centered: mean scores: 2.50 to 3.49);

Beginner (teacher-centered: mean scores from 1.50 to 2.49).

(24 years) are the pseudonyms used for the four NSTs in this study.

Personal relevance.

This sub-category of CLES measures the extent to which teachers/students feel that students understand the relevance of school science to their out-of-school lives. The four NSTs promote continuity between school science and everyday applications in various ways. Below are examples from Amy and Bill.

Amy consistently provides connections between the material being learned in class and the outside world in the form of discussions about related careers, environmental issues, and science-related social issues. She regularly invites her students to share and compare personal experiences that they think may be related to the concepts being discussed. For example, her lesson on 'acids and bases and their connection with food' (year 3 videotapes) caused students to make connections between acids and the Ph of the stomach, antacids, spicy food, stress, stomach ulcers, advertisements on heartburn, chemists making money, acids in batteries, acids in fruits, and acids in drugs. Teachers and students touched on Mark Twain's insight regarding food, McDonald's, food manufacturers, diets, weight watchers, nutrition, etc. When she taught *fluid pressure*, Amy asked:

Examples in real life situations?
Examples in daily life? What about in nature? ...Where, ... who would measure pressure on a daily basis? (Amy, year 1 and 2 videotapes).

Bill, through both his actions and words frequently conveyed to his students that science is everywhere in their daily lives.

...at times students have a question and I say I think we can best answer this by going outside. We were studying electricity and our school has some new tennis courts and they asked, how do those lights come on? ...and I say, well, I really don't know, let's go find out. ...we just got up and went outside. And we looked around and we found that there was a timer with a coin slot that you put coins in. Of course, then they all wanted to get quarters and put it in the light and see how long it lasted and how much light a quarter would buy and things like that (Bill, year 2 interview).

These teachers do not portray science as an abstract subject. According to the constructivist perspective, the classroom environment should engage students in opportunities to:

- a. experience the relevance of school science to their everyday interests and activities, and
- b. use their everyday experiences as a meaningful context for the development of their formal scientific knowledge.

Scientific uncertainty.

This sub-category of CLES is concerned with perceptions of science as a fallible human activity that is embedded in a cultural context and embodies human values and interests. The new science teachers in the study often connect their teaching to natural phenomena and social/controversial issues. They demonstrate that science is useful but has limitations, because it is a human explanation of nature. For example, Amy:

... awareness of values like managing the earth's resources and things like that ...there's issues

about cloning and genetics, and in vitro fertilization. There are issues and things that are going on that are not clear cut – in genetic engineering – that are not, um, totally approved by everybody... debated over issues... test tube babies... whether there's really a bad ozone problem... (Amy, year 1 and/or year 2 interviews).

When Caster taught *sound and noise*, his students brainstormed in small groups and came to a decision on their group definition of noise. Later, during whole class summary, they searched for similarities among the different definitions, debated, and negotiated to arrive at a whole class consensus. Caster told his students:

We want to come with one main consensus...just the way science works, that is, scientists work.... Don't worry about your personal differences...noise as sound which upset...depends on personal preference...still a lot of grey areas. That is how it is in science (Caster, year 2 videotape).

According to the constructivist perspective, the classroom environment should provide students with opportunities to be skeptical and critical about the nature and value of science so that they are able to achieve meaningful learning through the process of posing questions and finding their own answers.

Critical voice.

This sub-category of CLES is concerned with student development as autonomous learners that are able to legitimately question the quality of their learning activities. Videotape observations indicated that all four new teachers were very successful in establishing a friendly, yet respectful learning environment.

The establishment of a safe, non-judgmental classroom environment encourages students to speak.

It's alright to disagree. It does not mean all have to have the same criteria [for a rubric] we have here. It's up to you to vary... (Caster, year 2 videotape).

...they [students] were complaining...[that they] need more requirement on...projects and what exactly are they supposed to do. And I said no, that's exactly the opposite. I don't want more requirements, because I won't get their creativity they're supposed to be showing me (Drake, year 3 interview).

Drake was willing to accept students' concerns while also demonstrating his accountability to the class. During the interview, he described how he explained his innovative teaching approaches to a particular student who was extremely upset with project work, as well as to her parents and the administrators. He concluded with an explanation of the ways that students learn from having a critical voice:

She has made incredible improvement from where she was at the beginning...when she had to build the roller coaster [first project work]...she has learned and made a drastic improvement on how she attacks a problem. At the beginning it was a lot more complaints – I don't think I can do it, and I am scared to do it and things like this and now [later project] she goes right at it and attacks it... (Drake, year 3 interview).

According to the constructivist perspective, the classroom environment should not favor technical curriculum interests (e.g. covering the

curriculum content) to such an extent that accountability for classroom activities is directed largely towards an external authority. Rather, the teacher should be willing to demonstrate his/her accountability to the class by fostering critical attitudes in students towards the teaching and learning activities. This can be achieved by creating a social climate in which students feel that it is legitimate and beneficial to:

- a. question the teacher's pedagogical plans and methods, and
- b. express concern about any impediments to their learning.

Shared control.

This sub-category of CLES is concerned with another important aspect of the development of student autonomy, namely, students sharing the control of the classroom learning environment with their teachers. The videotapes and interviews provide evidence of ways that students were involved in providing material or content (for example: newspaper articles, advertisements, or food labels) and data (for example: electrical readings) that drove the lessons. Constructivist teachers sometimes use student suggestions, ideas, or questions to drive their lessons, and they respond to different interests or needs by allowing each student to elect an appropriate learning activity that is of interest to him or her individually. These are some of the ways in which constructivist teachers give students some control over their learning. In the classrooms of teachers from the constructivist preparation program, in some cases, student autonomy even extended to determining and applying assessment criteria, such as developing rubrics and writing quizzes.

For example in Drake's year 2 videotape, his students were the ones who made the decision on the criteria of a rubric that guided the assessment of their project on light.

... want you to create something special of your own. I'll show you the basics of the assignments; you show me what you want. You determine criteria of assessing your project (Drake, year 2 videotape).

Caster shared his satisfaction with the effectiveness of allowing students the autonomy to write the quiz themselves:

...I said: "Okay, we're going to take a quiz in a week and what I'd like you to do, is I would like you to write the questions for the quiz" and I gave them [students] certain parameters by which they had to follow – like I said no true/false, no multiple choice, no vocabulary questions. And it was an interesting environment because the students dove right into it...I had a little bit of modeling, just to get them started, but I was really amazed in how well they could write higher order questions and it was across the board, it was from the lower ability to higher ability students were doing a terrific job at it and it was good...the learning environment mainly constitute them,...my role just being coach to prompt them on (Caster, year 1 interview).

According to the constructivist perspective, students should not be required to adopt the traditional role of compliant recipient of a predetermined pedagogy controlled entirely by the teacher. Rather, the teacher should invite students to share control of important aspects of their

learning by providing opportunities for them to participate in:

- a. designing and managing their own learning activities,
- b. determining and applying assessment criteria, and
- c. negotiating the social norms of the classroom.

It is pertinent to note here that the four NSTs and their students agreed that the least constructivist aspect of their teaching/learning was shared control (SC) of teaching/learning (refer to Tables 2 and 3.) Likewise, both comparative samples (the new teachers [NTs] from ten general preparation programs [Salish I Research Project, 1997] and the experienced constructivist teachers [ETs] [Yutakom, 1997]) were also perceived as being the least constructivist in this sub-category (compared to the other five sub-categories of the CLES). This result is consistent with the results of past studies that made use of the CLES instrument. The measure of perceptions regarding Shared Control (SC) is generally rated lowest, regardless of whether student autonomy was looked at from the new teacher perspective (Tillotson, 1996; Waggett, 1999; Lew, 2008) or from the student perspective (Salish I Research Project, 1997; Taylor et al., 1994; Tillotson, 1996; Lew, 2008). This outcome may not be unusual given the fact that the teachers are still in the process of developing their pedagogy and establishing a curriculum. These challenging tasks require time to refine, and thus, many new teachers are more control-oriented in their first few years of teaching (Brooks & Brooks 1995; Lounghran 1994). Apparently, the ETs became less control-oriented. However, they too

tend to encourage greater student criticism of teaching/learning strategies versus allowing them to share decisions concerning those strategies. These findings suggest the need to explore further what causes teachers to not exhibit shared control more often than they do. How can teachers be helped more to practice these behaviors?

Using the “Model of Constructivist Behavior Expertise Level” (MCBEL) (refer to Table 1), all the new teachers (both from the exemplary program and those from the ten general programs) were classified as “Beginner Constructivist” (mean scores = 1.50 - 2.49) while Yutakom’s experienced teachers (ETs) were classified as “Transitional Constructivists” (mean scores = 2.50 – 3.49) in giving students shared control of important decisions pertaining to learning (refer to Table 3). This paper will not delve into the possible differences in interpretation of statement in this sub-category of CLES. It should be noted, however, that the ETs selected for the Yutakom’s study were nationally (USA) recognized constructivist teachers. Their surprisingly low scores for the Shared Control sub-category of CLES (despite observations to the contrary) led Yutakom to comment: “The scores suggest that the [experienced] teachers do not involve students in planning, conducting lessons, and assessing their own learning as much as constructivist philosophy would suggest is desirable” (1997, p.107). Similarly, in this study, while qualitative data does indicate the four NSTs shared control of learning with their students, student involvement in important decision-making pertaining to learning may not occur on a regular basis or as frequently as is desirable

(for achievement of student-centeredness). Also, the four NSTs could be perceived as ‘similar’ to NTs from general preparation programs in that:

Students were much more likely to believe they could express their opinions about classroom instruction [Critical Voice, CV] than to believe they could actually play a role in the decision making about that instruction [Shared Control, SC] (Salish I Research Project, 1997, p.20).

On the other hand (as discussed earlier), student perception of autonomy for the CV sub-category placed the four NSTs at a higher expertise level (Early Constructivist as compared to Transitional) than NTs from ten general programs across the United States who were involved in Salish I (1997.)

Student negotiation.

This sub-category of CLES is concerned with negotiation amongst students, including the amount of verbal interaction that students engage in while building their scientific knowledge. Videotape lessons indicate that the structure of classroom lessons of the four NSTs often focus on engagement in small group discussions, brainstorming, whole class discussions, summaries, presentations, debates, group projects, and other activities that involve interaction between students.

Have a safe learning environment where everybody feels safe to be able to speak and do the activities...and working together, you know, cooperative efforts with other students (Amy, year 2 interview).

According to the constructivist perspective, the classroom environment should not require students to

learn in isolation from other students or to regard the teacher or textbook as the main arbiter of viable scientific knowledge. The four NSTs demonstrate their belief in this idea by taking steps to ensure that their classroom environment provides students with opportunities to:

- a. explain and justify their newly developing ideas to one another,
- b. make sense of other students' ideas and reflect on the viability of those ideas, and
- c. reflect critically on the viability of their own ideas.

Attitude toward class.

This sub-category of CLES measures teacher/student interpretation of student attitudes about important aspects of the overall classroom-learning environment, including:

- a. student anticipation of the learning activities,
- b. student perception of the worthwhileness of the learning activities, and
- c. the impact of the learning activities on student interest, enjoyment, and understanding.

Evidences of ways the four new teachers strived to ensure positive student attitude were numerous. Some examples are the innovative projects in Drake's classes, the rockets that Caster's students designed and launched, and Bill's class trip to an amusement park to learn about physics. The new teachers believed in stimulating their students' curiosity and often used science-related social events outside of school to accomplish that objective.

...start with a question or some sort of challenge or even just explaining ...what they...be able to apply...if I ...say, "Why is

DNA testing on O.J. Simpson critical?" I think the they [students] might care to learn about DNA fingerprinting a little bit more than if I said, "Today we're going to learn about DNA fingerprinting". Setting the stage for something's meaningful,...is just so important (Amy, year 1 interview).

During Drake's 2nd year, his lessons on light, lasers, and fiber optics consistently motivated learning by capitalizing on the novelty and newness of demonstrations performed by the teacher and the students. There were over half a dozen exclamations of "cool," "wow," and "neat!" from students as they viewed red-lighted water shooting out of holes in a plastic bottle. The students showed similar enthusiasm for the many other demonstrations about refraction and reflection of colored light. Curiosity was often evident in student remarks such as "How did you do that?" and "But where did you start from?" Excitement was also evident as students exclaimed "Oh my" and shared laughter. It was clear that these students enjoyed their science classes.

Positive attitude was very evident in almost all the classes of the four new teachers. Other ways the new teachers made learning exciting and positive included extending learning outside the classroom, decreasing dependency on text books, and establishing a non-judgmental and respectful learning environment.

Discussions

Unfortunately, other than CLES, different qualitative and quantitative instruments were used to triangulate data for teacher use of constructivist teaching practices in each of the three studies. Hence further detailed in-depth comparison cannot be carried

out between the sample new science teachers (NSTs) of this study and the sample of experienced constructivist teachers (ETs) or other NTs.

Recall the earlier two questions: Which factors might be responsible for the differences in student perceptions of the extent to which their new teachers (NSTs versus NTs) use constructivist teaching practices? Which factors might explain the reasons that the NSTs match ETs in their perceived use of three sub-categories of constructivist teaching practices? This researcher argues that the four NSTs had the advantage of preparation from a program with a concentration on constructivism. Pre-service students need to be provided with a model of constructivist learning situation so they can learn the requisite skills to teach in a constructivist manner (Shymansky, 1992; Brooks & Brook, 1993; Raizen & Michelsohn, 1994).

A limitation of the presented quantitative data from CLES is the sample size (four NSTs and the number of their year two students, $n = 169$) from the program with a focus on constructivism. It can be argued that perhaps individual characteristics of the four NSTs, such as school culture, socioeconomic status, and other uncontrolled variables contributed to their increased use of constructivist teaching practices as compared to NTs in general. However, the four NSTs were not specifically selected for purposes of comparison, but rather based on the availability of complete datasets due to their participation in an original longitudinal study. Appendix A shows background information about the four NSTs. They ranged in age from 24 to 38 years and taught in different school cultures. Their undergraduate

GPA ranged from 2.6 to 3.38. They were typical graduates and representative of the program. In this report, it is not possible to delve into an extensive qualitative description of the constructivist teaching practices of the four NSTs, but data is available upon request.

The findings in this study contrast with the generalized findings of the large scale Salish I Research Project (1997) sponsored by the US Department of Education that followed new teachers (NTs) from 10 different programs across America from years 1 to 3 of their teaching. Salish I was shocking, because it illustrated that much of the idealism of new teachers disappeared as they found themselves alone and, often, without the support of caring mentors that they had experienced during student teaching. "Most [new teachers] reverted to much more teacher directed instruction and more textbook dominated content" (Salish I Research Project, 1997, p.35). In contrast, the NSTs in this report held onto many constructivist teaching practices. This controversy mimics the widespread disagreement in the literature about the overall impact of teacher preparation programs. In an Education Commission of the State report, Michael B. Allen summarizes the ongoing disagreement: "How well the nation [USA] is doing at preparing teachers is a matter of considerable debate" (2003, p. 7). He concluded that "While the research on teacher preparation is limited, it does provide guidance for policymakers and others on a number of issues, including the value and impact of certain kinds of coursework, field experience..." (p.viii).

In order to support the contention that program experiences aid NSTs

in developing constructivist teaching strategies, I will provide a brief description of pertinent program features. All faculties are knowledgeable about constructivism and purposefully model a variety of constructivist teaching practices (not merely those measured by CLES) in their classrooms. Pre-service NSTs were explicitly taught the theory of constructivism throughout the entire sequence and across all coursework. Pre-service NSTs were also consistently encouraged to put into action constructivist teaching approaches in every step of the program. These opportunities are described below:

- (i) Extensive field experiences (up to 149 hours prior to student teaching, followed by 16 weeks of student teaching) take place over four consecutive semesters in several different schools and at different grade levels while under the supervision of carefully selected veteran teachers who are knowledgeable about constructivism.
- (ii) Ongoing reflective practices, including regular self-analysis and group critiques of videotapes of the field experiences, teach pre-service teachers to analyze lesson effectiveness based on constructivist epistemology and current research findings.
- (iii) Ongoing development of a research-based rationale for effective constructivist teaching practices (via journaling, changing earlier rationale, and verbally defending reflective essays) occurs throughout the four semesters of the program.

In short, the program directly addresses the principles of constructivism and ways to use it to frame

teaching. When they started as full-time teachers, the new teachers in this study were mentally prepared with student-centered knowledge and beliefs that enabled them to translate these principles into classroom practices.

Finally, support for the NSTs does not stop at the end of student teaching. Research has shown the importance of induction programs in maintaining the idealism learned during teacher preparatory programs. What type and form of induction program is needed to ensure that fledgling science teachers are not left unaided to cope with the unexpected stresses and demands of running a class alone? How do we provide new teachers with the mentoring and support necessary to ensure that they do not drop out of the teaching profession? Roehrig and Luft (2006) recommend specialized support programs for beginning science teachers. In an earlier study, Luft, Roehrig, & Patterson asserted: "...when supported by a science focused induction program, beginning teachers experienced fewer constraints, and were more likely to implement inquiry-based instruction in their classrooms than did secondary science teachers receiving general induction support or no formal induction support versus generalized induction programs or no induction at all" (2003, in Roehrig & Luft, 2006, p. 964). New science teachers from the program in this report were regularly mentored by professors from the program. Their induction was specific to science teaching practices that are oriented by constructivism. This was done mainly by means of a one-on-one support system throughout the duration of the study (through their third year of teaching).

Another limitation of this study is the lack of data on student achievements that would objectively capture the effectiveness of constructivist teaching. Further and better research should, "Make the connections to student achievement as explicit as possible" (Allen, 2003, p. ix). On the other hand, there is much literature in different parts of the world that indicates research and instructional programs that make use of constructivist instructional strategies lead to improved science learning by producing students who are able to think critically and use their knowledge in new situations (Bybee & Fuchs, 2006; Hand & Peterson, 1995; Loughran, 1994; Schifter & Simon 1990; Trumper, 2006; Yager & Weld 1997). Furthermore, the National Science Education Standards (NSES) (National Research Council, 1996) were developed based on constructivist principles about how people effectively teach and learn.

Conclusion

Teaching is an art. While it is not easy to prepare constructivist science teachers, study after study indicates that beginning teachers can be student-centered. Preparing science teachers who can think and who can guide their students to think is vital for a digitalized world in which information (and misinformation) is just a click away.

Constructivism is one of many intellectual practices that can be used in education. Although it is extremely important that we consider other methodologies in teaching, constructivism remains an extremely valuable tool, because it allows teachers and students to develop a comprehensive understanding of science and its real

world application. The practice of constructivism should be explicitly addressed during the preparation of all new teachers. Preparation such as this will give students and teachers alike a profound understanding of the complexities of science. Yager sums it well: "Science education must portray science and constructivist practices if the reforms envisioned by NSES are to flourish" (2004, p. 26).

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Appendix

Appendix A: Selected Background Information: Four NSTs

Pseudonym	Personal	Teaching Position	Student Population
Amy	Caucasian, Age=38 Undergrad GPA=3.38 Major: Biology Minor: Chemistry	Rural high school School enrollment: 750	Middle Social Economic Over 95% Caucasian Less 5% African American
Bill	Caucasian, Age=32 Undergrad GPA=2.60 Major: Geology Minor: None	Suburban middle school School enrollment: 1,150	Low to Middle Social Economic Over 85% Caucasian 10% African American less 5% Hispanic/Latino
Caster	Caucasian, Age=33 Undergrad GPA= 3.15 Major: Biology Minor: none	Suburban high school School enrollment: 1,400	Mid to Upper Middle Social Economic 80% Caucasian 15% African American less 5 % Hispanic/Latino
Drake	Caucasian, Age=24 Undergrad GPA= 3.23 Major: Biology Minor: Chemistry, Physics	Rural high school School enrollment: 1,550	Low to Middle Social Economic (90%) 98% Caucasian less 1% Asian American less 1 % Hispanic/Latino

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