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Learning as you Teach

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Abstract. Researchers and practitioners have become interested in strategies teacher preparation programs implement to assist novice teachers with analysing their teaching. While many new educators have not been afforded ample opportunities to analyse student work, they acquire expertise in this area. However, new teachers often lack the knowledge to incorporate the constructivist model of teaching. The constructivist model benefits the teacher and the student; the teacher is better able to analyse their practice and the student is afforded deeper learning opportunities. A case study was conducted with science teachers using the ESTEEM instrument for observing constructivist pedagogy. The results revealed that in-service teachers inclusive of new teachers need to reflect on their teaching intentionally, and observe the connections between lesson objectives and student outcome. If this is emphasized much more in teacher preparation programs, it would be of benefit to new teachers as they gain more experience in engaging learners.

Keywords: Teacher preparation programs; constructivist; analysis of teaching; deeper learning opportunities

Introduction

For the new teacher who is embarking on a career in science education there is great anticipation and desire to be an effective teacher. With a lot of science background and a few teaching methods courses under the belt, the fresh idealist sets out to make positive impacts on young minds. The teacher wants to be effective, and instil in the students the same excitement and wonder about science that the teacher has had ever since the teacher was their age. The teacher has visions of wide-eyed, eager-to-learn students anxious to engage in any of a host of science activities that the teacher has prepared. The teacher wants students to learn.

Proficient teaching, and progression of science content in science education is described in the Next Generation Science Standards (NGSS, 2013). What those standards say to the teacher is well supported in education research and many teachers have become successful at adopting and incorporating the standards into their daily routines in the classroom. These are the teachers who do have students who are wide-eyed with wonder and inquiry, who form questions which guide the direction of their own learning, and who come to an accurate understanding of the science concepts they uncover.

But who are these teachers and how did they become good teachers? To the new teacher, the seasoned, effective classroom teacher makes teaching and learning, appear easy, fluid, and natural. In their classes, there is little evidence of discipline problems and there is obvious respect for the teacher by the students and for the students by the teacher. The new teacher tries to incorporate what he has observed into his own classroom, but the lesson does not flow smoothly and challenging discipline problems crop up at prime learning moments, diverting his attention and disrupting the environment he had worked so hard to achieve. The very things he saw the effective teacher do in his class do not seem to work in his own, at least not yet. But he knows what good teaching looks like and he knows that he hasn't been able to achieve that calibre of teaching for his own students.

The research done to identify good teaching and successful learning continues. Already, much is known about knowing and how it is acquired. The Next Generation Science Standards (NGSS, 2013) describe what is needed from science teachers, what they should know and practice, with the focus on developing science content progression for K to 12 grade. The new emphasis steers the teacher away from using textbooks to guide lessons and toward the use of inquiry. An emphasis on inquiry involves students in an environment of active learning, using higher order thinking similar to scientists. Inquiry is a powerful way of learning. We as humans are naturally curious about what we observe around us. We learn about the world surrounding us through science practices that use basic and integrated process skills. We then use tools that we have made to measure and observe the world, analyse the information, and then create models and explanations. We continue in this manner, applying the explanations and models to other observable phenomena or situations to confirm that the explanations are accurate. According to NRC (2000), we modify our ideas based on the differences discovered from prior knowledge and current information.

Science teachers mostly currently consider constructivism to be the most effective way to teach for meaningful understanding (Burry-Stock & Oxford, 1994). Teaching practices that demonstrate constructivist instruction and learning were highlighted by Yager (1991):

> Seeking out and using student questions and ideas to guide lessons and whole instructional units; accepting and encouraging student initiation of ideas; promoting student leadership, collaboration, location of information, and taking actions as a result of the learning practice; using student thinking, experiences, and interests to drive lessons; encouraging the use of alternative sources for information both from written materials and experts; using open-ended questions and encouraging students to elaborate on their questions and their responses; encouraging students to suggest causes for events and situations, and encouraging them to predict consequences; encouraging

> students to test their own ideas; seeking out student ideas before presenting teacher ideas or before studying ideas from textbooks or other sources; encouraging students to challenge each other's conceptualizations and ideas; using cooperative learning strategies that emphasize collaboration, respect individuality, and use division of labour tactics; encouraging adequate time for reflection and analysis; respecting and using all ideas that students generate; and encouraging self-analysis, collection of real evidence to support ideas, and reformulation of ideas in light of new experiences and evidence. (P.55-56)

One of the most challenging aspects of this approach to teaching is assisting the students in developing questions that are real, significant, and suited for investigation and that the investigation is worthwhile and possible given the resources available. Once the question is posed and is amenable to addressing within the classroom, student learning can be driven by the question and students can be empowered as they use higher order thinking, problem-solving skills, and their own experiences. Another challenge to this approach lies within the teacher's own belief system. Beliefs are changeable over time, but it is a tall order to bring about such a change without a very supportive environment.

Whether a new teacher is seeking to teach through inquiry or a veteran teacher desires to change his methods based on reform and the standards, a process over time will be required. For the new teacher, many beliefs are likely present, which may resist the teacher's efforts to use methods involving inquiry. After all, the new teacher, as a student, has been largely educated in more teacher-cantered situations. The veteran teacher who has developed his/her methods according to traditional behaviourist principles will be required to think and act in new ways. He/she will have to adopt new skills, behaviours, instructional activities and methods of assessment. For either teacher a change in attitudes and beliefs will be required. Convention has it that the change in teachers' thinking or beliefs will create new behaviours. However, research suggests that the opposite is true. Instead, changes in attitudes and beliefs usually come about when the teacher steps out in faith to use a new practice and discovers that his/her students are benefiting from the new practice (Antonetti & Garver, 2015; Guskey, 1986). It is this awareness of the benefits of change that produces the actual commitment to the new way of doing things. When the teacher finds that his/her students are learning from this new approach, he/she will likely expand the use of these new methods. It follows then that teachers need to undergo a sort of construction of concepts of their own. The new belief becomes the more accurate understanding, similar to the process of conceptual change that occurs when students learn. Teachers need to pay close attention to their own conceptual change as they grow in their teaching abilities just as much as they do to the conceptual change of their students (Prawat, 1992).

The objective and goal of this research was to discover by observing science teachers, inclusive of new teachers, whether they engage in some kind of informal and intuitive reflection, and pay systematic attention to the cause and effect relationship while teaching.

Literature Review

Recent research has shed light on whether the behavior of expert teachers has positive effects on student achievement (Harris & Garvin, 2013). The National Board of Professional Teacher Standards (NBPTS) assesses and certifies teachers who are considered to be very able, advanced, or teacher leaders in one of thirty different areas of teaching. A study was conducted by the NBTS. The study compared a group of teachers who were certified as compared to those teachers who were not certified. The certified teachers in this study possessed certain attributes of expert and advanced teaching to a greater extent than the non-certified teachers.

> They possess pedagogical content knowledge that is more flexibly and innovatively employed in instruction; they are more able to improvise and to alter instruction in response to contextual features of the classroom situation; they understand at a deeper level the reasons for individual student success and failure on any given academic task; their understanding of students is such that they are more able to provide developmentally appropriate learning tasks that engage, challenge, and even intrigue students, but neither bore nor overwhelm them; they are more able to anticipate and plan for difficulties students are likely to encounter with new concepts; they can more easily improvise when things do not run smoothly; they are more able to generate accurate hypotheses about the causes of student success and failure; and they bring a more distinct passion to their work (Bond, Smith, Baker, Hattie, 2000).

Student achievement from classrooms of the two groups of teachers was evaluated through written assignments. Bond et al. (2000) collected data from these writing assignments on the depth of student understanding of objectives included in some of the instructed units. It was determined that 74% of the student work samples obtained from the board-certified teachers demonstrated understanding that was more relational and more abstract. Only 29% of the student work obtained from the non-board-certified teachers had these characteristics. They concluded that the expert teachers who became certified by the NBPTS were better able to foster student development in the area of understanding that was richer, more elaborated, and more meaningfully interconnected with related concepts.

Expertise in the teaching field has been described in terms of a continuum with five separate stages of development (Dreyfus, 2004). In the first stage, a *novice* will determine his/her actions from the rules that he/she has been given. However, the rules that he/she follows to guide his/her behavior are not strongly associated with the environmental context presented in the classroom. Some examples of rules learned and applied without the specificity of context include "give praise for right answers," "wait several seconds after asking an open-ended question," and "never personally criticize a student." The novice recognizes isolated features of the environment and applies that specific, learned rule to respond to or guide the students.

The *advanced beginner* has gained some experience in coping with real classroom situations and pays closer attention to the context in which isolated classroom features present themselves. He/she recognizes other meaningful aspects of the situation that accompany the main feature. Just as a driver has learned to look at the speedometer as the main feature to determine when to shift gears and with experience, learns to recognize the engine sound change that accompanies the speed change, the teacher learns to recognize additional clues to help him make decisions. Instead of black and white rules, contexts understood through experience begin to drive teacher behaviors. This type of knowledge has been termed practical knowledge or "the wisdom of practice." Whether positive or negative, experiences that involve cases, incidents, successes, or failures are useful for guiding the teacher in future decisions. Practical knowledge helps the teacher know when rules should be followed or ignored, as the context serves to guide and determine teacher behavior. In other words, some rules become conditional. For example, a student with a low ability may interpret praise in some circumstances as communicating low expectations (Berliner, 2004). Even with improving practical knowledge, there is a lack of personal responsibility assumed for his/her actions that the teacher will gain later with improved proficiency.

Personal responsibility begins to take shape for the *competent* teacher. Prior to this stage, if the rules did not work, the teacher could have placed the blame of the outcome on being given inadequate rules. However, as the teacher gains experience and learns to recognize more and more situations that differ from one another only subtly, the teacher begins to adopt more complex plans or perspectives that have a more direct effect on the results. This teacher tends to be able to make a more conscious choice and to set priorities for what is important to attend to. Confusion and failure are prevalent as the result of some choices, but there is an increasing number of occasions when the outcomes are positive, sometimes surprisingly so. The teacher begins to experience more elation from these positive outcomes of student learning. Whether the teacher experiences a good or bad outcome, he/she accepts more of an emotional involvement in choosing the right perspective or action and taking responsibility, the teacher replays his performance in his/her mind, thinking of ways he/she would have done things differently or similarly. In addition, the teacher has goals that are more rational and has better tools with which to attain them. However, at this stage the competent teacher is not yet fluid, nor flexible in his/her behaviors.

Assimilation of experience, brought about by the strengthening of successful perspectives and actions and inhibiting unsuccessful perspectives, will aid the teacher in becoming *proficient.* Discriminating between situations becomes more important than assigning rules and principles. There is less need to make the determination of the appropriateness of an action because the goals become more obvious and the decision process going into a situation is more streamlined. The proficient teacher predicts classroom events more precisely and is more intuitive in recognizing patterns, but still needs to calculate and decide the best way to achieve that goal.

As the proficient teacher grows in expertise, the teacher is able to finely categorize a class of situations into subclasses, each of which require a separate decision and action. In this way, the *expert* teacher is able to distinguish situations that require specific subsequent actions from other situations that require a different action. This allows for more immediacy and intuition in responding to the situation. At this stage, the teacher's behaviors become more timely and fluid. What must be done given a specific situation simply is done. A chess player who has acquired the expertise to be considered a grandmaster can distinguish approximately 100,000 types of board positions and yet, can play at a rate of 5 to 10 seconds per move without hurting his/her performance. To be considered an expert, a teacher will discriminate between a similarly large numbers of situations and will respond fluidly without need for analysis or comparison of alternatives (Dreyfus, 2004).

Varrella (1997) studied the relationships between individual teachers' beliefs and their teaching practices. He based his research on the premise that expertise in constructivist teaching practices is directly related to the completeness and complexity of the individual's belief structure about constructivist and science technology and society (STS) method of teaching. Thirty-one middle school and high school teachers were involved in the study and represented a stratified sample of the 175 teachers who had participated in the Iowa Scope, Sequence & Coordination program. The sample was selected to provide the broadest range of abilities, perspectives and beliefs available from among the Iowa SS&C teachers. The Iowa SS&C Project which was conducted from 1990 to 1997 was funded by the National Science Foundation to enhance science teachers' abilities to teach effectively and along the lines of the National Science Education Standards. Some of the teachers involved were identified as experts. They were considered to be experts because they had shown a proficient ability to teach with a high level of expertise in using constructivist methods. This project sought to involve teachers in designing and planning learning experiences for their students consistent with a constructivist framework and a Science-Technology-Society context and the project set out to develop a group of leaders who would assist in designing such learning experiences for their colleagues.

The expert teachers that were identified through the Iowa SS&C Project had several common characteristics. They all had at least ten years of experience (except one teacher), were highly reflective, were active in reform efforts at the local, state, and national levels, were committed to life-long learning, exemplified by acquiring additional degrees and continuing education credits, and demonstrated consistency between observed classroom practices and self-described philosophy and strategies for teaching. These teachers demonstrated high levels of constructivist teaching, but also demonstrated the practice of a variety of strategies and approaches that, as a group, could not be categorized purely by a theoretical convention such as social constructivism or radical constructivism (Varrella, 1997, 2000).

Specifically, expert teachers involved in the Iowa SS&C Project demonstrated efficient use of higher-order questioning strategies and use of wait time to encourage more student responses and more thoughtful responses. They also emphasized learning that was hands-on and activity-based. They created an environment that allowed students to feel comfortable and safe to share ideas, challenges, and offer solutions to problems that they experienced in the class. They used textbooks for reference instead of the direction for lessons. They incorporated raw data in the activities rather than data that was formulated to work for cookbook validation experiments. They engaged students effectively both mentally and physically and they expected the students to pose questions, work individually as well as cooperatively, and allowed the students to modify and build on their ideas. They also showed commitment to being partners with the students as they valued students' opinions. They used a variety of assessments and did so frequently, including contextually consistent assessments of student learning and pre-assessments as planning and learning tools. They also showed an obvious commitment to their own continued learning of domain concepts. They were well-versed in content specific pedagogical practices, allowing for remarkable teacher flexibility and fluidity when adjustments in the curriculum or plans were needed. Impetus for these adjustments includes emerging student needs, appropriate tangents, and new student ideas stemming from their learning experiences. They designed their lessons and activities from a personal perspective and with relevance to their students. They taught science from an integrated perspective, incorporating concepts from physical, life, earth and space science. These teachers were very articulate when describing their values and beliefs about teaching and they were able to assist their colleagues in developing learner-centered teaching. Through the project, teachers benefited from working together in "learning communities". The teachers assisted one another to develop a deeper conceptual understanding of constructivist teaching methods and develop a more keen awareness of their students' cognitive development and abilities to apply knowledge to novel and unique problem-solving situations (Varrella, 1997, 2000).

The teaching performances of the teachers in the Varrella (1997) study were quantitatively scored using the Science Classroom Observation Rubric (SCOR) from the Expert Science Teacher Educational Evaluation Model (ESTEEM). Another ESTEEM rubric called the Teaching Practices Assessment Inventory (TPI) and a rubric developed by Varrella to assess teachers' beliefs (BALE) were also used. The SCOR is designed to evaluate expert science teaching from a constructivist perspective using Berliner's stage theory as described above as a continuum from novice to expert-like abilities. The rubric is used to score a teacher's performance during a single class period. The rating system used in the SCOR is based on a 1-5 point scale with a maximum total score of 90 for 18 items. The descriptions of five abilities along the continuum termed novice, advanced beginner, competent, proficient, and expert constructivist correspond to the points of the scale.

Methodology of Research

A case study was conducted with the use of the ESTEEM instrument for observation. There were 31 teachers in this study. The ESTEEM written comments were collected from the seven teachers. Written comments from the seven teachers collected through the BALE instrument were analyzed and four themes were revealed.

Observations of two teachers were conducted as they could be observed. One teacher was teaching a sixth grade class at middle school in the Midwest, and one who taught 10^{th} grade environmental/earth science at a high school in the Midwest region.

I observed the high school teacher, Susan (pseudonym), after speaking to one of the lead teachers in that school the day before. Susan was not notified that I would be observing until that day. The middle school teacher, Mary (pseudonym), was asked permission for my observing her class by the physical education teacher, whom I knew. But a date for observing her class was not communicated. Therefore, in both cases, the classes observed were mere snapshots of reality for the two teachers. The classrooms described below were not prepared in any special way for observation by a guest and there was no mention of my subsequent analysis of their teaching practice.

The ESTEEM rubrics were written to describe the ideal practices of science teachers from a perspective of teaching expertise as well as a constructivist perspective. The model is theoretically and empirically based and it is not likely that a teacher would exhibit expert-level scores on all of the rubrics. For example, in the study by Burry-Stock and Oxford (1994) the majority of the nominated expert science teachers were not strongly constructivist educators. The mean score of the SCOR of 46 nominated expert science teachers was 57.30 out of the maximum possible score of 90. Even though the teachers were nominated by college and university faculty and personnel from the state and regional departments of education, it was evident that either the people nominating or the nominees did not have a constructivist approach to teaching. It is interesting to note also that there was only a 50% agreement in the top quartile of the teachers that were sorted by the SCOR and sorted by the Student Outcome Assessment Rubric. Therefore, one should be cautious about what is considered expert (Burry-Stock & Oxford, 1994).

Result

There were 31 teachers in this case study. Seven of the 31 teachers in the study had an average score of 3.9 or higher taking all three instruments into account. This score placed these seven teachers into the proficient to expert categories.

Comments related to each theme highlight the teachers' constructivist focus. The theme of partnerships in the learning experience is highlighted by comments such as, "I try to create an atmosphere where we discover and learn together" and "The one dimensional aspect of the typical teacher-centered classroom disappears and barriers between teachers and students can be torn down and replaced with working relationships that more closely reflect real world scenarios."

Teachers noted the importance of relevancy in instruction through comments like, "…this science should be relevant and exciting to students, not because of the subject matter, but because the students initiate and take ownership in their science learning. The students can see the reasons to learn science and how it relates to our ever-changing world." The students are stakeholders in their learning experience. One teacher pointed this out by saying that her "classroom is conducive to an atmosphere that enables students to question and express opinions. The student is responsible to respect the opinions of others, contribute to discussions and activities, work in cooperative groups, gather information for research and inquiry, and be active in learning."

Assessment and performance as an aspect of teaching was also commonly stated from a constructivist view; one teacher "believe[d] that assessment is a form of communication where student and teacher work to find realistic products demonstrating student understanding" (Varrella, 1997).

Susan was not informed about my visit, but I had prior permission before I observed Mary. In the case of Susan, I would have liked to return the next day and observe more interaction with her students. The activity which was done the day I observed was the beginning of a week-long lesson plan. I anticipate that the score of the classroom observation rubric would be higher on subsequent days of the activity as the students would likely have more questions other than where to find materials and there would likely be more opportunity for her to gain information on their understanding of the concepts. However, I do believe that the whole activity (even though it was likely an activity performed by all classes) could have been introduced in a way that brought about greater inquiry. As it was presented, the activity seemed very cookbook-like and one could easily foresee the end-product just by reading through the "worksheet". There were analysis questions included on the worksheet but they had nothing to do with directly analyzing the data or results of the rocket project. It is also very possible that Susan would have strayed from the worksheet in subsequent class periods in order to address a student's question or misconception.

Susan did appear very comfortable during the entire class period and she showed great interpersonal relations with the students. It was evident that the students respected her. There was only one minor behavioral incident which was handled quickly and her handling of the situation was barely noticeable as she told the student without hesitation to go into the hallway. She handled the class with methods demonstrating experience but with little evidence of constructivist practice.

Mary's class was observed during her first hour and a HVAC contractor was in the middle of the room for the first ten minutes working on a ceiling mounted air conditioning unit. My audio recording of the class, as a result, did not pick up many of the student responses during that time. Mary took the opportunity to ask not only myself but the contractor as well to tell the class about our educational backgrounds and what we do in our jobs. Since the class was learning about electricity, Mary specifically asked the contractor about his experience with electrical work. The students seemed to enjoy the elicited information and took interest. Before Mary's class started, the principle was holding an impromptu meeting for all of the teachers and staff. This suggested to me that there was a real sense of community in that school.

However, as she started the class, it became evident by her style of teaching and apparent detachment from student understanding that she would not display constructivist practices. This was quite surprising to me at first. By the appearance of her classroom, one would think the opposite.

In retrospect, it would have been better to seek out a known expert teacher to observe. These two teachers, who graciously welcomed me into their classrooms, were examples of teachers who are clearly not teaching at a competent level. Fortunately, I have had the opportunity to student teach at both the schools and have witnessed some of the most effective teachers who very well may be expert-like or at least proficient in their fields. I will continue to search for teachers who demonstrate these characteristics that I have researched. I seek to continue this endeavor, for I desire to be a good teacher.

Conclusion

Researchers assert that while many teachers, including new teachers engage in some kind of informal and intuitive reflection, intentional and systematic attention to the cause and effect relationship should be taught and emphasized in teacher preparation programs. The implication of this study reiterates the significance of including intentional reflective practices with intentional focus on cause and effect relationship in teacher preparation institutions to engage students for further learning.

Most new teachers will struggle with the shift to focus on student achievement rather than on themselves as teachers (Wohlstetter, Datnow, & Park, 2008). According to Hiebert et al. (2007), there are two types of knowledge, skills, dispositions, and competencies that may improve and are essential to examine teaching over time. The first is pedagogical science content. It enables teachers to "analyze" the standards and determine specific goals for mastery. Additionally, teachers use this information to better understand how students will comprehend the subject, to refine specific concepts and to deepen students' knowledge of abstract concepts. Specific subject matter competencies afford teachers more opportunities for analysis of practice, thereby yielding improved teaching (Flooden & Meniketti, 2005). The second competence is reasoning which enables teachers to develop and test hypotheses regarding the cause-effect relationships between teaching and learning. Hiebert et al. (2007) grouped these competencies into the following categories: (a) student outcomes (b) measurable assessment to see if the student outcomes have been achieved, and (c) stating hypothesis for the lesson outcomes, and (d) using the hypotheses to modify the lesson.

The more specifically learning goals are described, the more useful teaching and analysis. Skillful specification of learning goals assists new teachers in determining which subject matter needs to be acquired and it will also improve competency in unpacking learning goals. When learning goals are specified, evidence can be collected to determine to what extent students achieve mastery.

Furthermore, the appropriate empirical observations can ensure that teachers are measuring mastery in the most authentic manner. Conducting appropriate empirical observations requires that the teacher distinguishes students' responses that are relevant from those that are irrelevant and identifies moments in the lesson where evidence of students' learning is apparent. McCutheoen (1980) emphasizes that new teachers often analyze their practice in terms of smooth implementation of activities rather than an anticipated change in students' thinking. Wheatly (2002) states that teachers' self-efficacy doubts might inadvertently support an understanding of their knowledge of student learning; questioning their effectiveness might cause a shift in their perspective. As a teacher begins to develop a hypotheses that link teaching and learning, the tasks must provide enough detail for the teacher to determine where learning gaps may occur. Additionally, if the learning goals do not incorporate conceptual learning, the teacher might implement quick instruction, immediate feedback, and effective and clear transitions from teacher modeling to student practice as a means of facilitating effective measurement on standards based testing (Hiebert & Grouws, 2007).

The new teachers use the student outcome, or cause-effect hypotheses as a rationale for carefully developed revision. Veteran teachers are able to better gauge how students will perform and on which tasks or point(s) within a lesson students will experience the greatest difficulty. They are also able to better identify strategies to address remediation when compared to novice teachers. Veteran teachers have been afforded several opportunities to hone research-oriented teaching skills; consequently they participate in gathering knowledge to accurately analyze their practice to improve their professional learning and student achievement (Antonetti & Garver, 2015; Marlara & San, 2002).

One of the more important aspects of this model is the need for reflection and purposeful change on the part of the teacher. The accomplished teacher does not stop learning or reflecting, becoming more conscious of their beliefs, understandings, and performance. It has been suggested that teachers develop teaching portfolios, write case reports, and involve themselves in regular discussions of their own practice with others.

Finally, the accomplished teacher is a member of a professional community. Within this community, the teacher both influences and is influenced by others with similar or dissimilar beliefs. In the case of pre-service teachers, the initial community in which he/she is trained is eventually replaced by a new community of learners (teachers) upon entering his/her first role as a classroom teacher. How much of that initial learning is transferred to the new context? There is an individual contribution by that teacher to the community and the community influences the new individual. In teacher communities, there are shared visions, commitments, a shared base of knowledge, adopted practices, and specific methods of teacher assessment which all come together to either enhance or inhibit the development of certain components of accomplishment derived from another context of learning (Harris & Garvin, 2013).

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