

Adopting a Student-Inquiry Stance for Teaching Genetics: A 10-year Autoethnographic Analysis

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While teaching genetics over a 10-year time span, I committed to change my pedagogy to include more student-inquiry. The main agent for this change was an epiphany caused by a difficult, yet enlightening experience with action research. My experience demonstrates that it is difficult to conduct authentic student inquiry in the high school science context and requires a shift of focus from traditional teacher-centered pedagogy to student-centered learning. This paper uses analytical autoethnography methodology (Anderson, 2006) to examine my support of student inquiry and the development of my pedagogical content knowledge (PCK) over a ten-year period. The level of student-inquiry will be characterized using the Chinn and Malhotra (2001) framework for evaluating inquiry tasks. The hexagonal model of pedagogical content knowledge from Park and Oliver (2008) is used as the theoretical framework for my pedagogical content knowledge change over the period of analysis. The ethnographic data examined in this study included documents such as project reports, curriculum documents, lesson plans, and written narratives. Data was examined using the hexagonal model pedagogical content knowledge components and written narratives to provide a temporal description of pedagogical content knowledge change. The findings indicate the transition towards increasing amounts of student-inquiry and changes in my personal pedagogical content knowledge. However, the change was slow and contained some pragmatic compromises and internal tensions.

The Trouble and Joy of Finding Reality

Have you ever experienced how an optical illusion distorts the perception of reality? Illusions can be fun; however, they are troubling if you discover the perception of your life's work differs from reality. This was the case when I conducted an action research study examining my teaching of high school genetics. The data I collected as part of my learning cycle demonstrated my perception of reality was distorted. This autoethnography is the story of my teaching before and after my action research epiphany, with the majority of the examination focused on the post-epiphany 10-year time span. The decision to change pedagogy was immediate. However, my transformation required more time as I adopted a student-inquiry teaching stance. Research demonstrates that implementation of student-inquiry requires skills, such as the generation of student-teacher discourse and specific management strategies (Marshall, Horton & White, 2009; Quigley, Marshall, Deaton, Cook & Padilla, 2011). These instructional differences may help explain why studies have demonstrated that student-inquiry instruction is difficult to enact for both experienced (Marshall, 2008) and first year teachers (Chichenkian, Shore & Tabaabai, 2016). My pedagogical transformation is best described as reflection and learning in action, with a commitment to use better sources for perception of classroom reality, namely, the students. The shift in focus to students and their own personal learning allowed me to determine how to teach via student-inquiry; something not necessarily achieved by completing the curriculum and core lab activities. This study starts with a brief summary of my early teaching, then moves through my action research experience to provide the context and setting of the epiphany that was the impetus for my pedagogical transformation.

Becoming a Teacher-Centered Instructor

In 1993, I accepted a teaching position right after finishing my teaching degree and a Master's degree in biology. I was surprised by how difficult it was to be a full-time classroom teacher. My assumption was that my experiences coaching sports, studying during my teaching degree, and two internships provided a good foundation for success.

Immersed in the teaching of four new courses, I found myself barely treading water while clinging to my textbooks as a life-ring. Through hard work, purpose, late nights, and countless mistakes, I grew the knowledge necessary to present lessons and manage my classes. I followed advice from sage teachers and found that my military experience served me well in commanding authority as the focus of a teacher-centered classroom. The administration and my fellow teachers were pleased with my attitude and capacity to manage my classes. I was happy, grew more comfortable, and was oblivious to the teacher-centered pedagogical path I had chosen.

Later in my first year of teaching, I was reassigned to a permanent position as a biology teacher. I was euphoric. No longer a replacement teacher and now situated in my biology comfort zone, I quickly made plans to instruct in the same manner in which I had been taught by my favorite high school teachers and university professors. These were my archetypes of perceived perfect teaching as I had connected with them as a student. They contributed to my success; thus, how could they be anything less than perfect? With my entrenched ideals of what I thought teaching should be, I forged onward with military efficiency. Years passed and I developed my content knowledge to prepare students for AP Biology, wrote two curriculum guides, and settled into a rhythm of teaching. I was on the top of my game and in firm belief that my knowledge served to enrich the lives of my students. It was a great time in my life.

I then transferred to a new school after thirteen years in my first school. I wanted to continue to teach AP Biology and higher-level courses, something my old school could no longer offer me. I had worked hard to be the best I could be for the top-level students and felt I deserved to continue teaching the high achieving students. In retrospect, this attitude was elitist and somewhat entitled. Regardless of what motivated the move, it would set the stage for a positive change in my pedagogy.

The Action Research and Epiphanies

In 2007/2008, I participated in professional development that was designed and hosted by Dr. Karen Goodnough (a professor within the Faculty of Education at Memorial University). I joined the project called Science Across the Curriculum, with the intention of addressing my students' problems with learning genetics. However, my participation in this action research project provided more questions than answers.

The project started harmlessly enough. I visited the Faculty of Education and was introduced to the research team who taught me how to reflect on my teaching through action research. I soon realized that the action research cycle and providing time for reflection was a powerful form of self-investigation. My reflective teacher research project fostered a deep introspection of my pedagogy. I examined my interactions with students and how I presented my lessons and the rationale behind my pedagogical stance. I questioned my ideals and beliefs about teaching high school science. Unfortunately, with regards to teaching genetics, the data demonstrated that my perception of being an effective teacher was not my reality.

Before the action research project, I felt my knowledge base and exemplary presentations were meeting the needs of all my students. The action research questions I developed were focused on the students and how to help them improve their problem-solving. However, analysis of the data verified that my instruction was teacher-centered, that I was like a talking head when I instructed, and that the polite students were likely suffering in their desks. I was not engaging students with activities, and the core labs we were conducting were not the type of inquiry to challenge the students thinking or allow them to engage like a scientist. This realization was disconcerting. However, this epiphany was the impetus for to me to change my pedagogy.

The Problems with Student-inquiry

Most science teachers I know are constructivists, and like myself, they believe students “construct their own set of meanings or understanding (psychological constructionism) or by means of language (social constructionism)” (Hassard, 2005, p. 172). The use of inquiry is appealing to constructivist teachers (Dostal & Klement, 2015); however, the concept of inquiry is “elusive for teachers” (Capps, Shemwell & Young 2016, p.956). Student-inquiry requires teachers to facilitate lessons, reduce teacher-centered pedagogy, and relinquish control to produce independent learners (DiBiase & MacDonald, 2015; Dunkhase, 2013). Many teachers “do not feel prepared to implement inquiry nor do they have the skill necessary to manage inquiry activities” (DiBiase & MacDonald, 2015, p. 33).

I asked myself: why did I experience many of the aforementioned problems with student-inquiry? Why would a trained biological researcher, complete with journal publications, not use student-inquiry to teach genetics? I realized that I had not properly applied my science research and biology content knowledge to improve my student-inquiry pedagogical content knowledge (Lee & Luft, 2008; Park & Oliver, 2008). At the time of my epiphany, I had no idea what PCK was. I did know that I needed to develop lessons to address the lack of student-inquiry; this was where I started.

Rationale and Research Questions

This analytic autoethnography will examine the transformation of my pedagogy, once the action research awoke my need for change. Since that project, I readily employed action research as a model for praxis and was swept up with self-inquiry. I wanted my students to engage in learning experiences similar to those I had during my teacher research project. Further, I wanted to increase the amount of student-centered inquiry in my teaching of genetics.

Over the next 10 years I would develop and improve lesson plans and activities to better support student-inquiry. This paper addresses the following research questions:

1. How did my support of student inquiry change my pedagogical content knowledge over time?
2. How did the number and quality of my inquiry tasks change over time? and,
3. What experiences and perspectives are associated with these changes?

Why Conduct and Analytical Autoethnography?

Autoethnography uses personal stories, which allow the author to reflect on their sociocultural contexts and how the contexts give meanings to his/her/their experiences and perspectives (Chang, Ngunjiri, & Hernandez, 2013, p. 19). In this autoethnography, I am visible in the data, demonstrate reflexivity with my personal experience, and engage in the subject of my inquiry (teaching genetics), demonstrate my vulnerability, and conclude with the open-ended notion that “I am not done changing as a teacher” (Anderson & Glass-Coffin, 2013). This autoethnography is analytical because it considers “theoretical and conceptual literature sources” (Chang, 2013, P. 119) and uses data along with narrative writing of my personal experiences (Anderson, 2006, p. 380). The analytical autoethnographic method is both attractive and appropriate for me. Introspection is a constant in my life and thus, I feel comfortable conducting a detailed examination of my thoughts in writing, finding patterns, and then framing my experiences using literature from the discourses of pedagogical content knowledge (PCK) and student-inquiry. The context of this autoethnography is my ten-year practice of high school genetics pedagogy in support of student-inquiry tasks. Analytic autoethnography is appropriate as:

...ethnographic work in which the researcher is (1) a full member in the research group or setting, (2) visible as such a member in the researcher’s published texts, and (3) committed to an analytic research agenda focused on improving theoretical understandings of broader social phenomena. (Anderson, 2006, p. 375).

As a biology teacher, I have an “intimate familiarity through occupation” with twenty-five years of teaching experience (p. 379). As a member of the teacher social world and within the context of this investigation, I am both a participant and an observer. Through my career, I have documented and analyzed my practice, as well as purposefully engaged in it (p. 380). It is the intention of this ethnographic writing to use the data and my personal experience to examine my beliefs, values, and actions as a science teacher, as it relates to teaching genetics.

Pedagogical Content Knowledge (PCK)

Teaching is a knowledge-driven profession and teachers display a variety of forms of intelligence during their daily functions, “amalgam” was the term used by Lee Shulman (1986) to describe the mixed functions. The study and description of teacher knowledge forms has captivated researchers since Shulman first described pedagogical content knowledge or PCK (1986, 1987). Shulman (1986) demonstrated that the longitudinal transformation of methods used to understand teacher knowledge, similar to this study, demonstrate an increase in the complexity of teacher knowledge to represent more than knowing subject matter (p. 5). Shulman described the act of teaching as complex and discerned the differences between subject matter or content knowledge (CK) and knowledge of pedagogical methods (Pedagogical Content Knowledge or PCK) (p. 6-7). Van Driel, Verloop and deVos (1998) define pedagogical content knowledge as a transformation of subject-matter knowledge, so that it can be used effectively and flexibly in the communication process between teachers and learners during classroom practice. They clarify that PCK can be derived by teaching as well as school activities such as professional development. This study will use the more recent Park and Oliver PCK definition as, “a teacher’s understanding and enactment of how to help a group of students understand a specific subject matter” (2008, p. 264).

Pedagogical content knowledge is a complicated amalgam and has a tacit nature that makes it difficult to represent (Shulman, 1987). The components of a teacher’s PCK have been incorporated into many models available in the literature (For review see: Berry, Friedrichsen, & Loughran, 2015). I strongly identified with the components of the Park and Oliver (2008) “hexagonal model” (Figure 1). The Park and Oliver model includes six components that interact through integration and reflection-in-action to produce PCK understanding and enactment. These components are: orientation to teaching, knowledge of assessment of science learning, knowledge of instructional strategies for teaching science, teacher efficacy, knowledge of students’ understanding in science, and knowledge of curriculum (Figure 1). Within this study, the pedagogical content knowledge components will be connected to data, narratives, and reflections on my experiences to form the framework for this ethnographic pedagogical content knowledge analysis.

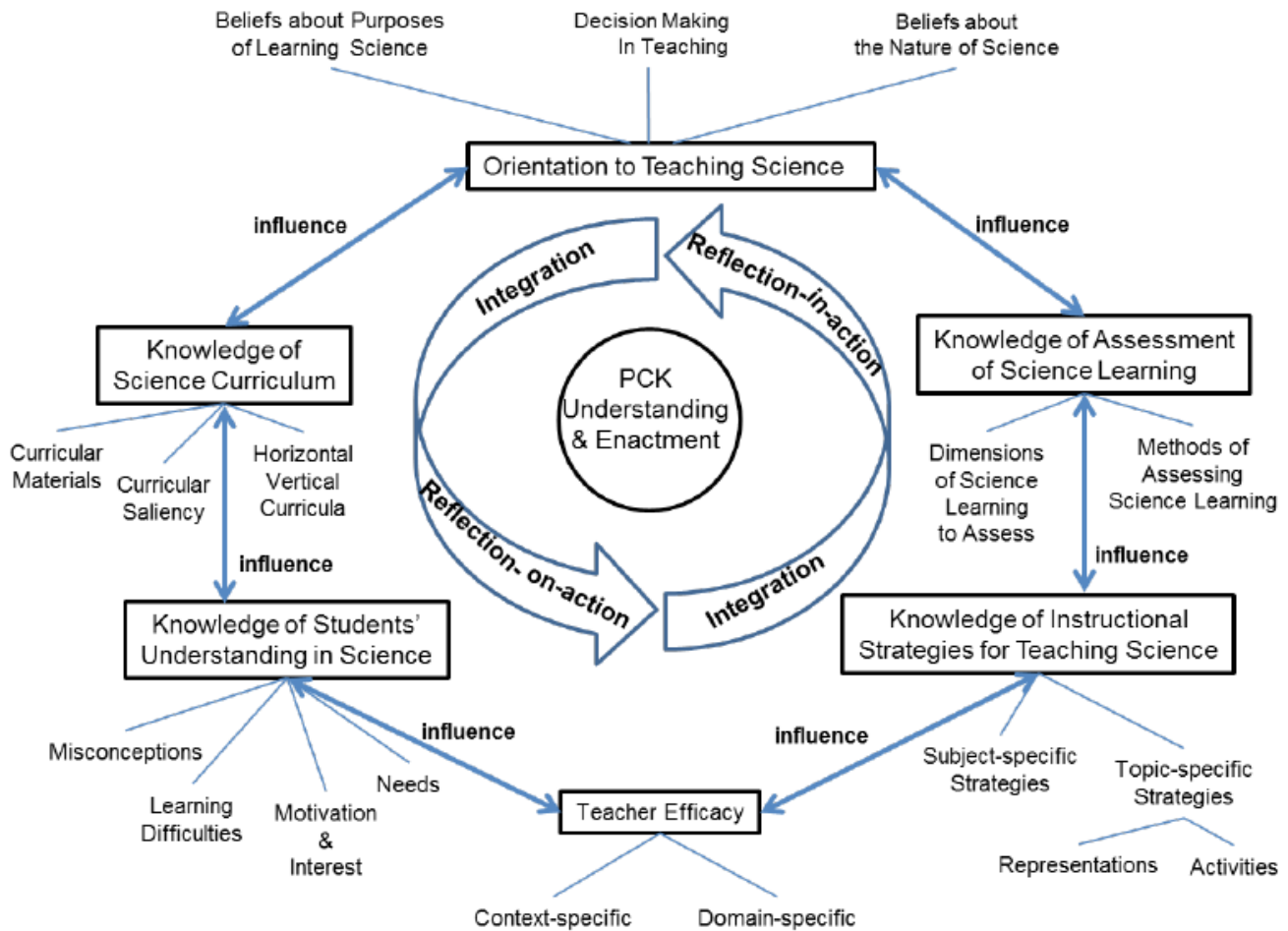


Figure 1. The Park & Oliver PCK model (2008).

Characterizing Inquiry and Student-Inquiry

I used the Chinn and Malhotra (2001) framework for evaluating inquiry tasks. Chinn and Malhotra sharply define student-inquiry tasks as ranging from authentic inquiry, conducted by scientists, to simple school inquiry tasks that help capture core components of scientific reasoning permitted (2001, p. 177). However, other models that evaluate inquiry exist in the literature. Examples include the Electronic Quality of Inquiry Protocol (EQUIP) (Marshall, Horton, & White, 2009; Marshall & Horton, 2009; Marshall, Smart, & Horton, 2010) and Reformed Teaching Observation Protocol (RTOP) (Sawada, Piburn, Judson, Turley, Falconer, & Russell, 2000). These are two of the many well-referenced instruments used to evaluate inquiry-based lessons and were the topic of an analytical comparison by Marshall, Smart, Lotter, and Sirbu (2011). While both EQUIP and RTOP offer a comprehensive evaluation of inquiry lessons (Marshall et al., 2011), given the large number of lessons and artifacts within this study that require evaluation, the Chinn & Malhotra rubrics were a pragmatic choice for a quicker analysis. In addition, the Chinn and Malhotra evaluation scheme of inquiry lessons permit classification of inquiry lesson according to cognitive and epistemological differences (p. 204).

This was important because of my support for student research projects – some of which examined certain drugs’ impact on cancer cell lines, termed “authentic inquiry” by Chinn and Malhotra. Briefly, these are the types of inquiry according to Chinn and Malhotra:

- Authentic Inquiry (AI) – scientific research in the form of case studies or experiments (p. 178).

- Simple Experiments (SE) – a straight forward experiment which usually examines the relationship between one independent and one dependent variable (p. 179).
- Simple Observations (SO) – where students make, observe, and describe objects (p. 179).
- Simple Illustrations (SI) – When students follow a procedure, without a control condition, and observe the outcome (p. 179).

Each of these processes differ in terms of the level and type of reasoning, the degree of guidance from the teacher, and the dimension of epistemology experienced by the students (such as theory ladenness of methods on p. 188). The rigor of the classification by Chinn and Malhotra clearly demonstrates when students are conducting an authentic science experiment or experiencing something simpler.

Data Sources

The data of this study included my personal documents that described: project reports, curriculum documents, lesson plans, and class notes (no student produced work was used as data). The study was supported by my habit of changing my lesson plans and keeping the old file, while saving the new modified file with a new name and date (ex. Protein Synthesis and Mutations Version 2_2015.doc). My lessons were examined and classified according to Chinn and Malhotra's (2001) method and organized chronologically to display changes in pedagogy over time. Transformation in lessons and teaching were coded using the pedagogical content knowledge components (Park & Oliver, 2008) and then blended with written narratives to support a temporal description of pedagogical content knowledge change.

Results/Discussion

The analysis of my teaching files demonstrates a steady proliferation of new student inquiry activities over the five to seven years "post-epiphany" (Table 1). There was also a concomitant decrease in the amount of class lecture time (Table 2). I cut back SmartBoard lessons by over 80% in 2-years and reduced PowerPoint by 50% over 8-years (Table 2). However, I continued the practice of presenting on the whiteboard, but never presenting more than 250 words. For a reason I cannot explain, the students seem to enjoy when I create a short written summary in front of them that makes sense to them. Perhaps they enjoyed how I try to make a complex concept simple, with an analogy, a story, by telling a joke or by using memory trick (or mnemonic device). For pedagogical content knowledge, this was a change in my Knowledge of Instructional Strategies for Teaching Science (Park & Oliver 2008) and I believe it occurred when I became a more student-centered teacher. This was the most improved part of my pedagogical content knowledge, particularly vital when students were conducting group or individual activities.

Connecting During Activities, Engagement and Observation

During activities, I found myself decreasing the distance between myself and the students, and I grew more comfortable in their proximity. For a person with strong naval connections, this parallels a historic final message sent by Admiral Nelson before he died at Trafalgar, "Engage the enemy more closely." Lord Nelson's message secured victory for the fleet and as a teacher, it reminds me that distance between the teacher and the students can be the enemy of learning. I see Nelson's last message as a call to move among the students during class and engage them through questions and conversation. I found that the closer I was, the more likely a student would ask me a question, even the quiet students. For encouragement, I would constantly say, "I'm ready to help" or "Are you stuck?" or "I'm bored, who has a question?" When I was physically close to the students or groups, they would be more likely to ask questions. I felt like I was no longer filling brains like water glasses; I was making

personalized memories. These productive and enjoyable interactions resulted from an increase in “Topic Specific Strategy for Activities” (Park & Oliver, 2008).

My proximity to students improved the quality of observing their actions. I noticed changes in student behaviour and learned more about my students (See Figure 1 – this is Reflection in Action). This caused me to change my lessons and improved an activity’s ability to challenge individual students (Knowledge of Students’ Understanding of Science, Park & Oliver, 2008). Some alterations focused on creating multiple copies of activities (DNA/Mutations Lab), to address issues of sharing answers by phone. While moving around the class, I observed students circumventing the inquiry process by copying another student’s work, through using pictures of completed work shared through text messages. My response was multiple versions of files and class management procedures to address the issues of sharing files, to increased active minds. However, for students who simply want the quickest answer, the constant tension regarding the use of phones to obtain answers (to likely avoid having to cognitively engage with the inquiry) remains.

As a result of my student-teacher conversations, I learned to be more selective with video files. Student feedback elicited during informal conversations resulted in the reduction of the number of presentations of long movies and an increase in the number of short animations and short movies (Table 2). For example, students reported that two of the long movies were boring and difficult to follow, resulting in the immediate removal of the films. Another reaction to multimedia learning was the development of a YouTube channel that contained short movies which, were ruthlessly vetted to ensure they met the needs of a novice watcher. Great care was taken to ensure that the course level was not exceeded. Students were asked on a regular basis whether they could comprehend the images, animations, and narration. “Be brutally honest” was a common phrase I used in conjunction with my quest for student feedback. Seldom was this qualifier required, as many students freely offered their frank opinion if a resource was confusing. This supported an increase in my Knowledge of Students’ Understanding in Science, along with Knowledge of Instructional Strategies for Teaching Science (Park & Oliver, 2008).

The rise in the number of animations and short movies coincided with the development of student-centered worksheets and the “Biotechnology Workbook.” This workbook was a guided flip-unit, where students would use class time to address issues and take part in activities (such as collecting Fly Project Data or demonstrations such as the DNA extraction). While students used iPads, their phones, Chromebooks, or other devices, I would wade among them, trying to find students with problems. I always wanted to create moments of one-on-one instruction to help foster understanding and trust. I designed resources that would create problems for students to solve; to challenge them in a safe place where I would come and help (Knowledge of Students’ Understanding in Science along with Knowledge of Instructional Strategies for Teaching Science; Park & Oliver, 2008).

Maximizing the Level of Student-Inquiry

While I worked hard to develop inquiry resources, a survey of Table 3 reveals that none of the in-class activities would be considered completely authentic inquiry, according to the Chinn and Malhotra rubric (2001). However, in the years following my epiphany, I found I could address the needs of students who craved authentic inquiry or learning science like a scientist through the biotechnology fair. Each year, I would support two to four students in conducting projects for the fair – all of which were authentic inquiry according to Chinn and Malhotra. These students were receiving the same gift of learning that action research provided me. I decided that supporting them was the best thing I could offer within the context of the amount of curriculum outcomes required for Biology 3201. I did not think of an authentic inquiry for genetics would be possible until I developed the Fruit Fly Project.

The Fruit Fly Project was initiated by a simple question: how I could I design a term project that will teach students about data collection and analysis? Over the span of two years, I developed the project and I can now say with great confidence that it was the simplest of my inquiry lessons and the most engaging. Each student was given a vial of flies with unknown provenance. Their task was to collect data that supports an inference about the genetic identity of the parents. I demonstrated the culture techniques, discussed how the fruit fly life cycle worked, and they did the rest. I always enjoyed the time wandering among them as they acted like scientists, collected data, and took responsibility for raising living things. Many projects were very successful. That was always great. Others struggled, which is often better. Cultures failed and had to be restarted. Students lost data. It got messy for them. Everyone learned (including me).

Many students found living animals both challenging and amazing. They freely supported each other, loved finding mutations, all while conducting research that addresses many authentic inquiry outcomes (Table 3). The Fruit Fly Project demonstrated a change in teacher efficacy (Park & Oliver, 2008), as I believed I could scaffold and support my students towards participating in and completing this major task. The Fruit Fly Project also addressed an issue related to the Orientation to Teaching Science – Nature of Science (Park & Oliver, 2008). The students were behaving like researchers in a genetics lab, controlling breeding cycles, asking many questions, and ultimately connecting genetics theory with reality in terms of fruit fly genetic expression. The only problem with the Fruit Fly Project was how it eliminated participation in the biotechnology fair. However, pedagogically this was a fair and inclusive exchange: two to four students per year for the biotechnology fair versus over 100 students conducting the Fruit Fly Project.

Teaching the Nature of Science

Pedagogical Content Knowledge for teaching the Nature of Science is complex and it also benefits from student-inquiry (Wahbeh & Abd-El-Khalick, 2014). This means that I learn more about teaching the Nature of Science when the students learn via inquiry. For example, inquiry activities like the Fruit Fly Project provide opportunities for students to act and behave like scientists, appreciate data collection, make observations, and use data to make inferences. Supporting this form of pedagogy, I learn and look for opportunities to teach the Nature of Science. Simple experiments, such as Modeling DNA and conducting an inquiry into the timeline of DNA Discovery, provides important contexts to appreciate the Nature of Science (Wahbeh and Abd-El-Khalick, 2014). The National Research Council recommends that Nature of Science be addressed more explicitly, as it may not emerge from engaging in practices (2012, p. 334). That's where my stories come in. While working with students in the lab, I would take the opportunity to describe how science has changed. We would engage in discussion about sexism in science and how competition played a role in the Nobel Prize for the discovery of DNA. I discussed why fruit flies, which share 90% of our genes, are a great model for the study of human diseases. I engaged the students in contemplating how a local researcher, Dr. Brian Stavelly, uses fruit flies to study cell death and Parkinson's disease. These stories have a local connection and are interesting to students.

Table 1

Chronological Incorporation and Modification of Student-Inquiry Activities †

Lesson	Fruit Fly Project	DNA/ Mutations Lab*	Karyotype Lab*	Modeling Activities (Chromosomes, DNA, Protein Synthesis, Gel Electrophoresis)	Pedigree Activities
Date of incorporation in pedagogy	2011	2008	2007	Chromosomes - 2008 DNA - 2011 Protein Synthesis - 2010 Gel Electrophoresis - 2009	2007
Modification(s) based on need to address student-inquiry or improve learning	2013	2010, 2012, 2015, 2017	2014	All demonstrations stayed the same except DNA - 2016	2009 and 2012
Total Number of Drafts	2	5	2	0	2
Final level of inquiry according to Chin and Malhotra (2001)	Authentic Inquiry with several deficiencies (See Table 3)	Simple Experiment with aspects of Authentic Inquiry (See Table 3)	Simple Experiment with aspects of Authentic Inquiry (See Table 3)	Simple Observations with aspects of Authentic Inquiry (See Table 3)	Simple Experiment with aspects of Authentic Inquiry (See Table 3)

Note. * = A Core Laboratory Activity for the Biology Course

† = Analysis does not include Mendelian Genetics Crosses, Biotechnology, Flipped Class Booklet, Plasmid Activity, DNA extraction, and Population Genetics Activities.

Table 2

Chronological Analysis of Teacher-Centered Instruction and Use of Multimedia

School Year	Smart Board Lessons	PowerPoint lessons (maximum used)	Animations and Short Movies*	Use of Long Movies (>15 min)	Presentation of Notes (1 board)
2008	8	6 - DNA Structure, DNA replication, DNA Discovery, Protein Synthesis, Mutations, and Biotechnology	0 and 0	4 (Mitosis, Meiosis, DNA, Protein Synthesis)	Yes
2009	7	6	12 and 0	4	Yes
2010	2	6	8 and 0	3 (Mitosis, DNA, Protein Synthesis)	Yes
2011	2	6	8 and 11 (YouTube Unit 3 playlist)	2 (Mitosis, DNA)	Yes
2012	3	5 – Merged and reduced DNA Structure and Replication.	6 and 11 (YouTube Unit 3 playlist)	2	Yes
2013	2	5	6 and 11 (YouTube Unit 3 playlist)	2	Yes
2014	1	4 – Stopped using Protein Synthesis	6 and 25 (YouTube Unit 3 and new Biotech playlist)	1 (DNA)	Yes
2015	0	4	6 and 25 (YouTube Unit 3 and new Biotech playlist)	1	Yes
2016	1	3 – Stopped DNA Discovery	6 and 25 (YouTube Unit 3 and new Biotech playlist)	2 (Mitosis, DNA)	Yes
2017	1	3 - DNA	6 and 25	2 (DNA and Fly	Yes

Structure and Function, Mutations, and Biotechnology (YouTube Unit 3 and new Biotech playlist) Project Movie from YouTube - 7 minutes)

Note. * = A short movie is less than 7 minutes and presented on a Smart Board.

Table 3

Characterization of Inquiry Lessons [†]by Cognitive Process from Chinn and Malhotra (2001). “Yes” denotes the activity has the properties of Authentic Inquiry.

Cognitive Process	Fruit Fly Project	DNA/ Mutations Lab*	Karyotype Lab*	Modeling Activities (Chromosomes, DNA, Protein Synthesis, Gel Electrophoresis)	Pedigree Activities
Generating research questions	No - SE	No - SE	No – SE	No - SO	No - SE
Designing studies - Selecting variables	No - SE	No - SE	No - SE	No - SO	No - SE
Designing studies - Planning procedures	No - SE	No - SE	No - SE	No - SO	No - SE
Designing studies - Controlling variables	Yes - AI	No - SE	No - SE	No - SO	No - SE
Designing studies - Planning measures	Yes - AI	No - SE	No - SE	No - SO	No - SE
Making observations	Yes - AI	Yes - AI	Yes - AI	Yes - AI	Yes - AI
Explaining results - Transforming observations	Yes - AI	Yes - AI	Yes - AI	No - SO	Yes - AI

Explaining results - Finding flaws	Yes - AI	No	No - SE	No – SO	No - SE
Explaining results - Indirect reasoning	Yes - AI	Yes - AI	Yes - AI	No - SO Yes – AI for Gel Electrophoresis	Yes - AI
Explaining results - Generalizations	Yes - AI	Yes - AI	Yes - AI	No - SO	No - SE
Explaining results - Types of reasoning	Yes - AI	Yes - AI	No - SE	No - SO	No - SE
Developing theories - Level of theory	No - SE	No - SE	No - SE	No – SO	No - SE
Developing theories - Coordinating results from multiple studies	No - SE	No - SE	No - SE	No – SO	No - SE
Studying research reports	No - SE	No - SE	No - SE	No - SE	No - SE

Note. AI = Authentic Inquiry, SE = Simple Experiment, SO = Simple Observation,

†= Does not include Biotechnology Projects that satisfy all Authentic Inquiry cognitive requirements except Developing Theories (both level of theory and coordinating results from multiple studies). Analysis does not include Mendelian Genetics Crosses, Biotechnology Flipped Class Booklet, DNA extraction, Plasmid Activity, DNA Fingerprinting Activity, and Population Genetics Activities.

- = A core Laboratory Activity for the Biology Course

Therefore, teaching the Nature of Science was a weakness in my teaching, but student-inquiry through the Fruit Fly Project facilitated growth of pedagogical content knowledge in this area (Park & Oliver, 2008).

Overall Feelings Post-Epiphany

The use of student-centered inquiry techniques made me feel like I was reaching more students. Contact with students was more direct and classes were designed to involve some form of activity or demonstration with an increased student-centered focus. At times, it required balance. Some students liked notes and disliked the activities, others could not wait to check their flies during the project. Classes currently contain many students, often over 30, and each individual may have a different learning agenda. My changes in pedagogical content knowledge improved my ability to detect student needs, plan better lessons, and believe that they are capable of behaving like scientists. Below is another analogy that encapsulates my present work as a teacher facilitator:

I see the students as my guests in a restaurant. I am the waiter that must determine who is hungry, who is thirsty, and how they want their lesson cooked. Making a lesson taste good is a *bricolage*: a creation that is composed of many parts. Teachers are bricoleurs and their abilities are summed up nicely by Crotty's (1998) description of social researchers:

The focus is on an individual's ability to employ a large range of tools and methods, even unconventional ones, and therefore on his or her inventiveness, resourcefulness and imaginativeness. So, the researcher-as-bricoleur 'is adept at performing a large number of diverse tasks.' (p. 49)

A good lesson is a bricolage that is formed by presentation methods, knowledge, attitudes, management, and more. Pedagogical content knowledge is a concept that attempts to make explicit the knowledge forms needed to be a teaching bricoleur. This analytical ethnography demonstrates how hexagonal model components of PCK from Park and Oliver (2008) grow as a teacher becomes a great bricoleur. Finally, how did pedagogical content knowledge elements combine to impact my teaching?

Aspects of PCK Changed and Educational Significance

The reduction in teacher-centered instruction resulted in more teacher-student contact and facilitated social learning of the teacher and students in genetics. The largest changes in my student-inquiry pedagogy are found in the following Park and Oliver PCK model components: orientation to teaching, knowledge of instructional strategies for teaching science, teacher efficacy, and knowledge of students' understanding in science. The analysis did not demonstrate a significant change in my knowledge of curriculum and knowledge of assessing science learning. However, over the course of the 10-year period the number of major tests decreased from 6 to 4, while the number of minor evaluations, informal evaluations, and portfolio items increased. These changes were not caused by a change in style of evaluation and were merely a conscious time management strategy to increase the amount of time for learning.

My orientation to teaching science was radically altered by my action research experience. My pedagogy changed from teacher-centered instruction to student-centered learning. The genetics lessons, student activities, and student-centered learning data are able to document and describe this change in my pedagogy. This study demonstrates that when a teacher is trained to use a model for praxis, they may experience significant progress in professional learning. Reflection was the gift of action research and it produced a conscious "reflection in action" (Park & Oliver) which resulted in my pedagogical content knowledge development. There are some tensions involved with a change in pedagogy and the concomitant growth of pedagogical content knowledge. Teaching that supports student inquiry results in changes in workload with direct student contact and increases aspects of pedagogical content knowledge. Increased pedagogical content knowledge for support of inquiry growth changes learning environments, teacher facilitation levels, and produces more opportunities for student social learning. It makes teaching tiring, but it also feels good.

Finally, why did this take 10-years to change my pedagogy?

As stated previously, learning to teach via student-inquiry is challenging (Capps, Shemwell & Young, 2016). Long-term high quality professional development and conducting research are both excellent scaffolds for successfully developing inquiry-based pedagogy (Capps, Crawford & Constas, 2012; Miranda & Damico, 2015; van Zee, 2006). In contrast, short-term professional development often fails to produce inquiry-proficient teachers (Marshall, Smart & Horton, 2011). Research shows that professional development and professional learning communities are crucial to increasing the number and quality of high school science inquiry lessons (Blanchard, Osborne, Wallwork & Harris 2013; Marshall 2008; Miranda and Damico, 2015). However, I had no community as I was the lone teacher instructing genetics in my school. Over ten years, I was fortunate to have supportive administrations

and the Memorial University action research experience to support me during these changes. With the support by my association (Centennial Fund, Newfoundland and Labrador Teachers' Association), I added another year of research. Action research had transformed teacher life to praxis towards student-inquiry, with the majority of the activity dedicated to developing the lessons for student-inquiry (See Tables 1 & 3). I had to learn via reflection in action with my students on a year-by-year basis. The pace of change towards student-inquiry was slow and featured the internal conflict between devotion to change and pragmatics of teaching a course that includes a high-stakes final exam. In the end, the seminal feature of learning to support student-inquiry is reflection in action, where each student may act to inform you about yourself and your practice on a daily basis.

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