Reflections on How Teachers and Students Learn Science

Finding Practical Solutions to Solving Secondary Science Cognition Problems; Using the Ways of Knowing to Connect How Teachers and Students Learn Content in Secondary Science Education

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ABSTRACT

This paper includes ideas behind students thought processes the inquiry and the analysis of classroom methods. The study includes reflections from Biology and masters level science education students who were asked to complete a survey about two particular guided inquiry lessons, and the general use of resources during practice, application and processing lessons in the classroom. This research is a springboard to address cognition and its ability to help formulate practice, application, and processing skills that drive the enhancement and engagement of conceptual understanding of secondary science concepts. Students were asked to reflect on teaching with regard to resources, practice, application and process. The following ideas are also addressed in the paper; how students learn science, and ways to understand the stages of development in cognition, scientific inquiry and reasoning skills.

Keywords: experiential inquiry, cognition, secondary science education, PISA-Programme for International Student Assessment, OECD- Organization for Economic Cooperation and Development, TIMSS-Trends in International Mathematics and Science Study

INTRODUCTION

COGNITIVE PATHWAYS: THE RESEARCH PERSEPCTIVES

Research about cognitive pathways can be established through a doctorate programs in secondary science education. It is apparent that the thought process of cognition connects with the ways of knowing in secondary science content. Students understand science by formulating and adapting the knowledge they capture to connect to logical practices. From a secondary science educator’s perspective students tend to be more engaged when applying technical ideas in terms of concepts. Student learn to reason out scientific ideas while practicing experiential enquiry through instructional strategies , the use of scientific resources and dialogue about the proper use of the application and processing of scientific ideas. Students process ideas from the left brained rational functioning such as structural, analytical, verbal and the right brained intuitive functions such as visual, spacial, and random patterns. In this way they can see the whole verses the parts.

The book the Teaching Gap provides insight into how to pilot the study. Graphs and charts represent seatwork time spent on practice, application, and process in countries such as Germany, Japan and the United States. The data was compiled from 8th grade math classrooms documented from the T.I.M.S.S project, an international math and science study. The attempt is to answer the following questions in this study; any questions not answered will carry over to future research, 1.) Is secondary science education growing with regard to the ways of knowing as it connects to the conceptual cognition and content? 2.) Can guided inquiry and the proper use of resources and questioning help teachers and students practice, apply, and process science concepts and content? 3.) Can reflection, reasoning and critical thinking in the science classroom engage and enhance conceptual learning? 4.) Can resources a.) provide students with the skills necessary to question and dialogue about proper science concepts, b.) allow for differentiated teaching and learning styles that increase an equal distribution of time while practicing, applying and processing science information?

HOW OTHER CULTURES LEARN SCIENCE

Japanese culture learns math and science starting with the problems first using a left, right brained holistic approach. The Japanese create a story line and an element of student and teacher engagement that opens up avenues for dialogue to reason answers via student and teacher. The Japanese teachers also complete lesson studies that allow educator to gather collaboratively to solve a research question about their lessons through professional development. More time is allotted at the black board with lessons and research questions. Germany spends more time in seat work but uses more complex problem solving methods.

A recent publication about how well students from the other 64 countries responded on the (PISA) the Program for International Student Assessment according to the OECD the Organization for Economic Cooperation and Development, places Shanghai China as first in Math, reading and science, Singapore second in math and 4^{th} in science.

WHY IS THE U.S. FALLING BEHIND ON THE PISA?

The truth is we spend more money per pupil than any other country excluding Luxembourg, and it isn't increasing achievement. The United States ranked 14^{th} in reading, 17^{th} in science and 25^{th} in math. When comparing how the U.S. student are competing on the PISA one needs to understand that students from other countries taking the test in the U.S. perform the same as their fellow students in other countries. America the melting pot takes in many students from underdeveloped nations. Some of those nations are reporting last in reading. A book by Dr. Robert Weissberg, states that U.S. experts fail to confront the obvious truth that 80 percent of a schools success depends on two factors, the cognitive ability of the child and the disposition he or she brings to class, not on texts, teachers or classroom size.

HOW STUDENTS LEARN SCIENCE IN AMERICA

Reflections from Cognitive Specialists

The book the Art of teaching Science by Jack Hassard has many constructs for learning science as depicted in chapter five. In this chapter Jerome Brunner, Director of the Harvard Center for Cognitive studies, believed that students learn best through discovery. Brunner said that, "knowing is a process rather than accumulated wisdom of science presented in text books."

Brunner discussed guided intrinsic motivation. He broke that down into components of curiosity and uncertainty, structure of knowledge, motivation and developmental cognition. The curiosity and uncertainty included students understanding discrepant events and their ability to explore ideas in a concept map framework. According to Brunner there were three modes of the structure of knowledge; A set of actions, (enactive representation), A set of images or graphics that stand for the concept (iconic representation), and A set of symbolic or logical statements (symbolic representation).

Brunner describes motivation as the learner developing techniques for providing feedback on his or her own. The development of cognitive structures includes Piaget intelligence models and mental structures addressed by Anton Lawson and John Renner. The chapter goes on to explain concrete reasoning patterns, sociocultural theories on learning, cooperative learning, the feminist perspective, situated cognition, and communities of practice.

Reflections from the National Research Council

According to the National Research Council students must; 1.) Draw on past experiences, and teachers must provide opportunities for students to explain discrepant events and come to terms with short comings in every day models, 2.) Students must use narrative accounts of knowledge and tools to get the organization of knowledge around key concepts, 3.) The learning must support meta cognition. Meta cognition means to be able to reflect on our own thinking. It includes producing information that is needed, to be conscious of our own steps and strategies during the act of problem solving, and to be able to trace or reflect and evaluate the productivity of our own thinking. "Engaging children in science, then, means engaging them in a whole new approach to questioning…It means questioning the typical assurance we feel from evidence that confirms our prior beliefs, asking in what ways the evidence is incomplete and may be countered by additional evidence." Magnunsson and Palincsar

KNOWLEDGE OF WHAT IT MEANS TO EXPERIENCE SCIENCE

How should we teach about critical thinking and be able to incorporate it into the curriculum?

Robert Ennis & Paul Boisvert both are credited for their research based in critical thinking related to concept development, cognition and reasoning, the philosophy of science including causality, best-explanation of inferences, and test reliability and validity. Their ideas include concern with assumptions, bias, and causality.

The Foundations of Experiential Inquiry

John Dewey created the foundations for the discovery of experiential learning through experience, conception of learning; experience the ideas, and concepts vs. big ideas and metaphors. "Like other exploratory processes, (the scientific method) can be resolved into dialogue between fact and fancy, the actual and the possible; between what could be true and what in is in fact the case. The purpose of science inquiry is not to compile an inventory of factual information, not to build up a totalitarian world picture of Natural laws in which every even that is not compulsory is forbidden. We should think of it rather as a logical particular structure of justification beliefs about a Possible World- a story which we invent and critique and modify as we go along, so that we can make it, a story about real life." Sir Peter Medawar

The products of scientific inquiry, facts, concepts, principles and theories

Such ideas include forms of science learning, things science students expected to know, applications and risks of science and technology on science careers, and societal issues that can be resolved trough processing the science and technology.

One should be able to teach with critical theories on learning which include constructivist perspectives, sociocultural perspectives, and behavioral perspectives. The constructivist approach such as conceptual change theory uses meaningful learning as opposed to rote learning and critical validity claims. There should be an element of surprise. Students must relate new information to what they already know and create a mental scaffold that they attach new concepts to.

For conceptual change a teacher must

1.) Help students become dissatisfied with their existing conception.
2.) Help students achieve a minimal initial understanding of the scientific conception.
3.) Make the scientific conception plausible to students.
4.) Show the scientific conception as fruitful or useful in understanding a variety of situations.

The theory in practice uses effective questions and resources in the classroom along with the guided inquiry. The application to learning style includes brain - based concepts for science teaching. The four types of learners are described as; imaginative, analytical, common sense learners, and dynamic learners.

What Students Can Learn in Science

Table 5.1 (Hassard) p.170 They can learn about

***knowledge products of science enquiry** (facts, concepts, principles and theories)	***act upon or apply information** (evaluative, manipulate, solve problems)	*** Internalize values** (about the utility and risk of thought and conceptual skills, and who does science)
***Nature of the scientific enterprise** (world view, methods, habits of thought, approaches to problems)	***Learn** (strategies to seek and acquire new information and to seek and acquire new skills)	***Assess self** (interest in science, capacity to do science)
***Values and attitudes** (of the scientific community, one's racial or cultural group, one's family)	***Produce knowledge** (question, test, evaluate)	***Make choices** (about studying science, science careers, and applying science knowledge and skills to daily life)

HOW HAS SECONDARY EDUCATION GROWN WITH REGARDS TO THE WAYS OF KNOWING

Historical Perspectives of Scientific Reasoning and the Development of the Ways of Knowing and Scientific Inquiry

History of the Inquiry

Observation and Inferences through reflective cognition

In order to know where we are going with respect to reason in secondary science education, and how students think and learn about science, we have to be able to reflect on the history of where we have been. Science is a body of knowledge, formed by a process of continuous inquiry, and encompassing the people engaged in the scientific enterprise. Science is a dynamic process. During the 16th and 17th centuries there was a birth of empirical science. Prior to that Plato's & Aristotle's used logical authoritive arguments for deductive methods based on universal ideas and with little interest in verification. Renee Descartes is credited with the development of beginning attempts at defining empirical methods for inquiry.

Descartes believed that to objectively question one must break the task down into fundamental pieces, study the parts in order of increasing complexity and generalize the results of observation. He proposed that rationalism and thought are the basis of knowledge and that assumptions are made of preexisting knowledge. The frame of thought at that time was for people to think for themselves to discover truth *by using* careful observation and critical thinking.

The development of rational thought through induction

Francis Bacon later describes empirical methods and objective interpretation. Bacon began with observations and inductive reasoning. He proposed that experiments can have negative results. He sought ways to eliminate error resulting from bias, prejudice or ignorance of the observer. Scientists find truth and knowledge in natural phenomenon revealed through observation. Scientists discover what exists. Logic can become a problem when making inferences from specific observations.

The Burden of Proof - deductible truth

Scientific inquiry through deduction was presented by Hume, Locke, and Berkeley in the 19th century. Logical positivism made generalizations that must be tested and verified by experience. Observations may not accurately describe the event. For example (All swans are white). A solution may come from deductions of cause and effect observations.

Experimental testing of generalizations proves their accuracy. The results can be positive to verify conditions or negative to refute the conditions. Thus the scientific method was developed. Polanyi criticized positivism approach concerning data collection. Here creative collection should be part of the data collection, tacit knowledge is internal, preconscious based on ideas that we know more than we communicate. Bronoski discussed values in science. He proposed a community effort in growth of the individual.

Paradigm shifts and scientific thought revolutions

A commitment to paradigms took place by Thomas Kuhn, who talked about the structure of scientific revolutions. He claimed that theories rational and objective are confirmed and refuted by experiments. Paradigms are universally recognized theories that provide solutions to a problem. “Normal” science continues when the paradigm is not in revolution. Science revolution occurs when there is a shift from one paradigm to another. There is always a resistance to the new paradigm. For example it took 20-30 years for Gregory Mendel’s genetics research on pea plants to be accepted by the scientific community.

Enquiry as conjecture or refutation became popular because of Karl Popper. Popper proposed that we eliminate error as we accrue knowledge. All sources of knowledge should be welcome. Scientists must determine accuracy of knowledge. Observations and intuition are not always reliable. Therefore, knowledge advances through examination and modification of earlier knowledge and grows through error.

REFLECTION ON HOW STUDENT LEARN SCIENCE

In a doctorate advanced techniques of math methods course taught at the University of Akron, students were asked to read a book entitled , <u>The Teaching Gap, Best Ideas from the World’s Teachers Improving Education in the Classroom</u>. This book tells a compelling story of an international study of math and science. After reading and watching the videos from the study I began to analyze my own secondary science teaching. The part in the book that struck home was chapter 4, *Refining the Images*. In this chapter, Germany, Japan and the United stated were compared for their amount of seatwork time in practice, application and process. The study took place in 1993. Japan spent the most amount of time roughly 41% on practice, 15 % on application and 44 % on process skills, compared to Germany, 89 % practice skills, 6% application and 4 % process skills and the United States 96% practice skills , 3.5 % application and less than 1% process skills. The results were staggeringly low for the United States.

From a science teacher’s perspective

The Methods

A survey was used to evaluate the amount of time spent using resources when practicing, applying and processing science instruction taught in a high school Biology 2 course, a regular Biology and Biology 101 course and data from advanced techniques of secondary science course taught at the University of Akron. The Biology 2 course consists of 24 students ranging from sophomores to seniors, with an equal amount of boys and girls in the class. The regular Biology class is composed of all freshmen. Students rated seat work time on a scale from 0-100% for each category of practice, application and process skills. In addition students rated the inquiry bases lessons and general lessons. Students were also asked to reflect on the same skills.

The Resources Used in the Study

The resources used for this study included; inquiry based labs, labs through Carolina Biology and Science Kit, the manipulation of Biology equipment, a wireless laptop and projector, DVD player and VCR, interwrite wireless tablet, a Discovery School multi-media kit with DVD’s, Modules with DVD’s through the National Health Institute of Science, the internet, Camtasia, e-field trips, Biologycorner.com, science journals, such as The Science teacher, Science World, Issues from the Journal of the College Science teaching, field trips, on-line e-portfolio’s, books, workbooks, and case studies. The above resources as well as Springboard an interactive internet site that allows the instructor to post content and interact with students through an on-line discussion board to teach a masters level science methods course.

Responses from the High School Biology Students

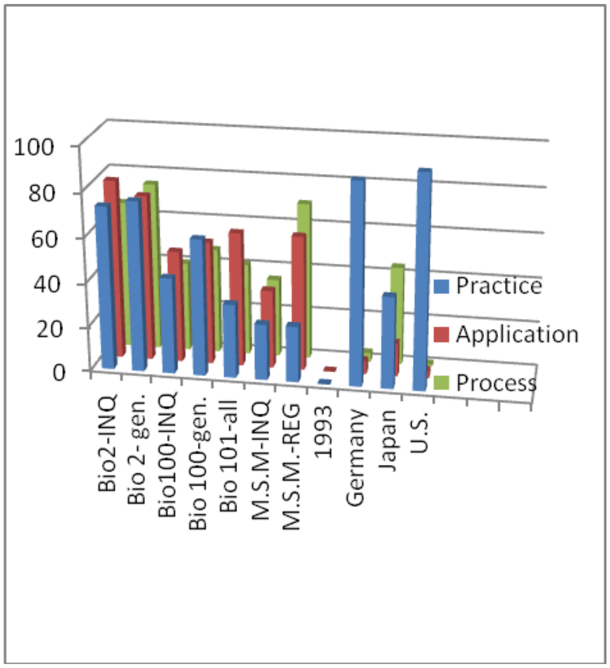
The responses were averaged. The results for the high school courses are as follows; The Biology 2, (represented by Bio 2 INQ on the graph) inquiry labs were rated at 76% practice, 74% application and 75% process. The regular lessons (Bio 2 General) on the graph were rated at 73% practice, 80% application, and 66% process. The results to the survey included Biology Inquiry labs (Bio 100 INQ-on graph) 43% practice, 50% application, and 40 % process. The use of everyday resources and their evaluation of everyday class work showed the following results; (Bio 100 Gen.) 61% practice, 55% application, 47% processing. Once again there are about 18 students with an equal amount of males to females in that class. The Biology 101 (Bio 101 all) class results were from inquiry labs and regular everyday work. Their results included 33% practice, 60% application, and 41% process. That class consists of 16 students with more girls than boys. The results are amazing when compared to the 1993 study. To test the hypothesis that the correct resources can get students to questioning and dialogue about proper concepts, allow me to teach to different learning styles, and spend more time with practice, application and process. This study implies that is possible.

When students use meta cognize reflect and interpret, they become engaged and intuitive about the results and they process the science faster. Freshmen generally struggle getting started with skills needed to met cognize. However, in time they gain a momentum towards understanding how to process the inquiry and critical thinking.

Results from the Advanced Techniques of Secondary Science Education maters level students

The science methods course includes 15 professionals with undergraduate degrees and master's degrees in science but who have a wide array of professions such as chiropractor, lawyer, polymer chemist, pharmacist, and M.B.A. The graduate students have come back to complete a licensure in secondary science education. The graduate students have come back to complete a licensure in secondary science education.

The secondary science methods course responded with averages of 25% practice, 35% application and 35 % processing (M.S.M.INQ) during inquiry peer teaching. The results for the regular lessons (M.S.M. regular) responded with averages of 25% practice, 60% application, and 70% processing skills. The following graphs the results to the surveys in all of the classes discussed above. (Scales from 0-100 for each of the practice (blue), process, (red) and application (green) the implications should discuss the effect of using the resources and the inquiry)



Reflection from students in the high school biology courses

The reflections from students in the high school classes, "I think it is necessary for us to learn, do and think…in the cellular respiration lab we were able to pick out the variables to form our own solutions…I think that the resources that we use in this class really helps me understand the process of thoughts…the inquiry helps me because I am a kinesthetic learner…In my eyes you have helped me learn to critically think a lot more than I am used to…. You give us random questions about what we are learning about and we have to think on our feet...the cellular respiration lab was fun because you got to pick the variables and had to think how to get the co2 production from the digestion of the yeast…by breaking things down and having proper resources it can help us to fully understand the information…over all thinking (process) is what we do in class and we follow it by applying it to the labs…."

Reflections from the students in the advanced techniques of secondary science reflections

Reflections from the students in the advanced technique course, "I enjoyed having a demonstration of guided inquiry. After seeing this, I feel I have a better idea of the "big picture…I think the peer teaching will be a good experience."..“The amount of time we spend on ‘paper work’ is de minimus. Since we are all into our careers, I find it beneficial that we do not spend class time on paper work, as we can do it out of class as needed, I would prefer to do more exercises where we apply what we read. Since we are transitioning from one profession to another, it would be beneficial to practice (‘get on our feet’) more of the concepts we have been presented in the readings, perhaps through individual or group presentations." "We do spend a significant amount of time engaging in critical thinking with regard to the class. The inquiry guided lessons have allowed me to view the hands on learning in a manner different from the years of labs I did while in school. It shows how inquiry guided lessons can, and should, reinforce the content being taught and how an inquiry based curriculum can lead to higher level critical thinking."

CONCLUSIONS

Understanding the past can help one to critically think about our present needs, with regards to resolving societal issues of the future, and to close the gap regarding theory and practice. We are at a time and place for scientific revolutions and paradigms shifts. One should be able to process scientific thought through cognitive pathways, conversations and critical reasoning about science content. Teaching students to use the proper resources and communication channels helps them to understand the practical skill and to apply the science methods. There is a significant amount of discussion and dialogue in the classroom about the lessons, content and concepts and the use of communication tools and questions. Students practiced listening to each other's responses. Students also played games to make sure to understand each other's presentations. Students were responsible for their own unique reflection and response with regard to content. This actually works to motivate students to provide something unique to the lesson.

Goals and Products of this Study

The few goals and products of this type of instruction in secondary education is to promote the following; active listening/proper communication skills, a conceptual understanding of science and issues related to social justice, exploration in science and science education. keener observation and inference skill, students being able to think and reflect for themselves /test their own validity claims, critical analysis skills to be able to practice, apply and process using resources, f.) the ability to reason and think about cause and effect/consequences, a greater understanding of how the technology benefits or assists with the other resources.

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