

# Exploring Preservice Teachers' Understanding about Scientific Inquiry Using a Water Chemistry Project

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April 2018

# Introduction

- TCH 247 is created and newly implemented from Fall 2018 as part of the elementary education program.
- The purpose is to provide all el. ed. majors with the background of scientific inquiry through authentic experience of scientific inquiry.
- Little evidence as to what kind of authentic experience is best of assistance for them to be confident about scientific inquiry, what are the challenges, how do they understand the complexity of creating new scientific knowledge, how do they develop instructional conditions that promote scientific inquiry, and in what way do they build their confidence about scientific inquiry?

# Literature Review

- Scientific Inquiry is recommended by ISBE, NSES and NGSS and became an ubiquitous term in science teaching and learning (ISBE, 2014; NRC, 1996; Achieve, 2013)
- Scientific Inquiry is an effective teaching pedagogy in understanding how scientific knowledge is developed. (NRC, 2000; Minner, Levy, & Century, 2010)
- Understanding how scientific knowledge is developed has been a key idea of teaching science for more than four decades (Heron, 1971; Minner, Levy, & Century, 2010).

# Cont.

- But, teachers have improper pedagogical background work to increase complexities and difficulties of how scientific knowledge is constructed (Zion, et al., 2007).
- Students' understanding of how scientific knowledge is well documented (Schwartz & White, 2005).
- To date, however, few studies identify patterns of evidence on preservice elementary science teachers' understanding of how scientific knowledge is constructed.

# Cont.

- ‘Scientific Inquiry’ identifies the following eight practices as essential for all students (NRC, 2012):
- (1) Asking questions and defining problems, (2) Developing and using models, (3) Planning and carrying out investigations, (4) Analyzing and interpreting data, (5) Using mathematics and computational thinking, (6) Constructing explanations (for science) and designing solutions (for engineering), (7) Engaging in argument from evidence, and (8) Obtaining, evaluating, and communicating information.

# Cont.

- Water quality is recognized as one of the major issues of the world including Illinois. In fact, there is a lack of knowledge about water quality within the general population of the U.S. (Hu et al., 2011).
- Water chemistry project is well perceived as a good way to practice scientific inquiry by collecting data and analyze to answer the research questions that come from the local water problems in Normal and Bloomington.

# Research Questions:

- How do preservice teachers develop an understanding of how scientific knowledge is developed?
- How do preservice teachers develop insight into the experiences and instructional conditions that facilitate their understanding of scientific inquiry?

# Methodology

- Quasi-Experimental Design with Convenient non-random sampling method (Patton, 2015).
- 10 Preservice Teachers in four groups participated; Groups 1 (n=4), Group 2 (n=3), Group 3 (n=3),
- Groups received a weekly guide with scientific inquiry and water sampling and analysis from the instructor.
- Data sources: (a) Reflection, (b) Focus-group interview (N=3), (c) Self-efficacy Questionnaire.
- Water Chemical Project - Implemented over one semester.

# Data Collection

- Data Collection: Water Sampling
  1. High and Low SES areas of Buildings in B/N.
  2. Tipton Park Water Pond, Bloomington, IL.
  3. A Stream by Anderson Park, Normal, IL.

# Cont.

- Before collecting water sample, all participants attended a session explaining on how to obtain a good water sample with safety lessons at the Hydrology Lab.
- Per Group: Collect three water samples (50 ml in each) in a small plastic bottle twice a week, sixteen data samples per week for eight weeks beginning the first week of September 2017.

# Analysis of Water Sample

- A set of collected water samples - sent to the Hydrology Lab at ISU for analysis.
- SES-related chemistry, Fluoride mg/L, Chloride mg/L, and Sulfate mg/L
- Analyzed data --emailed to students in one week.

# Analysis of Research Data

- Qualitative data (Reflection, Interview):
- **(a) Reflection:** Read each individual reflection several times to look for emerging patterns, themes, and relationships about participants' understanding of scientific inquiry instruction (Miles, Huberman, and Saldana, 2014).

# Cont.

- (b) Interview: Read the transcripts thoroughly several times by constantly checking and comparing by using open coding (Strauss & Corbin, 1998).
- Both (a) and (b) data, two experts will check the identified common experience, patterns, or themes, which helps secure the trustworthiness of interpretations (Maxwell, 1996).

# Analysis of Research Data

- Quantitative data: (Survey):

(c) Self-efficacy Survey (post) will be analyzed in descriptive stat.

# EACH GROUP'S RESEARCH

September – November, 2017

- GROUP 1 – Research Question:

How does water in drinking fountains compare in low Socioeconomic schools versus high Socioeconomic areas based on EPA standards?

- Key for Sites:

High SES Area Building: Hyatt, Lake

Bloomington, Lake Evergreen, Metcalf, Prairieland

Low SES Area Building : Washington, Irving,

Bent, Sheridan, School District Building 87

# Cont.

Site	Where?	Flouride mg/L	Chloride mg/L	Bromide mg/L	Nitrate-N mg/L	PO4-P mg/L	Sulfate mg/L
1	Tap	0.60795	145.36995	0.3398	0.409	1.1144	57.7701
2	Lake	0.2045	25.74765	0.1288	1.444	0	14.6039
3	Lake	0.24985	36.4993	0.1946	0.479	0	23.1434
4	Tap	0.58125	100.22415	0.2075	0.367	0.95215	37.6402
5	Tap	0.50265	70.98115	0.17275	0.342	0.9112	25.9957
6	Tap	0.83145	36.8406	0	0.7615	0.67285	18.2015
7	Tap	0.76345	22.9579	0	0.6535	0.6935	12.3701
8	Tap	0.88155	41.43	0.344	0.8225	0.79405	20.60755
10	Tap	0.8599	26.79645	0.074	1.1875	0	14.7245

## ■ GROUP Conclusion:

The higher SES areas around B/N are more closely in line with the EPA standards for clean water than the low SES areas.

# Cont.

## ■ GROUP 2 - Research Question:

Depending on the changing seasons, how do the levels of chloride in the water change?

### 6. Data & Analysis

Date Collected:	Chloride Level (mg/L)	Air Temperature
10/17/17	Sample A: 60.9487 Sample B: 58.8937 Sample C: 60.7679	56 degrees Fahrenheit
10/29/17	Sample A: 64.2359 Sample B: 64.366 Sample C: 64.1681	38 degrees Fahrenheit
11/11/17	Sample A: 72.8585 Sample B: 72.273 Sample C: 71.9678	34 degrees Fahrenheit
11/16/17	Sample A: 71.6977 Sample B: 72.7506 Sample C: 72.4572	30 degrees Fahrenheit

Note: Samples A, B, C are collected from the same spot of the pond in Tipton Park;  
Address: 2201 Stone Mountain Blvd, Bloomington, IL 61704.



# Cont.

- GROUP 2 - Conclusion:

As the season changes from fall to winter, the chloride level in the water increases, making it a harsher environment for wildlife and vegetation to be active and thrive.

# Cont.

## ■ GROUP 3 - Research Question:

How does the rise or fall of the temperature, wind, and humidity affect the levels of phosphate in the water?

### 6. Data and Analysis:

	Air Temperature	Wind Speed	Humidity	Level of PO4
Week 1 (11/1)	43 Degrees F	13 MPH	89	2.0747 mg/L 1.9259 mg/L 1.7883 mg/L
Week 2 (11/8)	38 Degrees F	7 MPH	69	1.8266 mg/L 2.0329 mg/L 1.7024 mg/L
Week 3 (11/15)	44 Degrees F	17 MPH	82	0.4413 mg/L 0.4137 mg/L 0.3869 mg/L
Week 4 (11/29)	42 Degrees F	10 MPH	49	2.1654 mg/L 2.1809 mg/L

Note: The location for all was at the Stream by Anderson Park;  
Address: 503 E College Ave, Normal, IL 61761.

# Cont.

- GROUP 3 - Conclusion:

The decrease in temperature, the increase in wind, and the decrease in humidity decreased the phosphate in the water of a stream in Normal, IL.

# Answering Research Question 1

- How do preservice teachers develop a understanding of scientific inquiry in real scientific research?

# Group 1 Reflection

- **Group 1- Lack of Scientific Knowledge:**

*“we knew that contaminated water is unsafe and undrinkable but not all of us knew exactly why and what factors contribute to water contamination-EPA standards become critical.”*

# Cont.

- Group 1- **Lack of Science Background:**

*“EPA protects public health by implementing the Safe Drinking Water Act (SDWA) provisions while working with states, tribes, and many other partners. Some of the contaminants that are regulated are microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, and radionuclides.”*

# Cont.

## ■ Group 1- Lack of Scientific Research Experience:

*“we talk more about what contamination is and why that is important for drinking water.... We still collect water samples and test them, but the analysis portion would need much more of a guide. .... we need to understand the chemical composition a bit more during the comparison and analysis.”*

# Group 2 Reflection

- **Group 2- Lack of Scientific Knowledge:**

*“the chloride levels do in fact make a difference in the water and are impacted by weather and the environment around us. The hands-on work we did to collect this data should be exactly the same as what scientists think and do.”*

# Cont.

- Group 2 – Lack of Scientific Research Experience:

*“By observing the growth in the plants and the effects the chloride has on the plant, we are then be able to apply this knowledge to the outside world and the chloride’s effects on sewers, ponds, fields and surrounding plants.”*

# Cont.

## ■ Group 2 – Confusion/Frustration:

*“We were confused by the data, which put us in a difficulty position to make the following conclusion because the data was not consistent, “As the season changes from fall to winter, the chloride level in the water increases.”*

- *“Looking at our data, level of PO<sub>4</sub> was 1.9 mg/L (11/1) and 0.41 mg/L (11/15) but it went up again like 2.1 mg/L (11/29). We were not sure what to do. We were frustrated b/c we did not have time to go back and double check it.”*

# Group 3 Reflection

- **Lack of Scientific Knowledge in Real Context**--- *“We also knew that global warming affected aquatic life on a large scale, but we don’t necessarily think of ponds and lakes when thinking about global warming. However, through researching this project we learned that global warming is much more complicated than previously perceived.”*

# Cont.

## ■ Group 3 -- Meaningful Learning:

*“Through using the scientific process, asking questions, observing, and experimenting, we were able to expand our knowledge while working with data in our own community.”*

# Focus Group Interview (N=3)

- Participants heard about the concept of ‘Scientific Inquiry’ last year in college in TCH 247.

- The Concept of Scientific Inquiry:

*“I guess it is like asking questions and explaining and observing so then with inquiry like it allows you to do that instead of teacher gives student answer, student writes down exactly what is supposed to be written, which is how my elementary school times were.”*

# Cont.

- *“as a college student I’m not as curious about science because I never had to be. It was always just we are going to learn about plants I’ll just wait until the teacher tells me what to do and then I don’t need to like think”*

# Cont.

## ■ Goal of Scientific Inquiry:

*“To be curious”*

*“To investigate well”*

*“To like make a hypothesis and confirm it or disconfirm it.”*

*“To create new knowledge?”*

# Answering Research Question 2

- How do preservice teachers develop insight into the experiences and instructional conditions that facilitate their understanding of scientific inquiry?

# Reflection

## ■ Group 1: Conditions of Developmentally Appropriate Instruction

*--“Students may not be aware that all of these chemicals exist in water. For younger grades, it would be overwhelming to cover the above information in depth, so we would talk more in general about what contamination is and why that is important for drinking water. They would still collect water samples and test them, but the analysis portion would be much more of a guided activity. In older grades the students would also collect water samples and test them, and we could start to cover the chemical composition a bit more during the comparison and analysis.”*

# Reflection

## ■ Group 2: Conditions for Applying What was Learned

*--“By observing the growth in their plants and the effects the chloride has on the plant, the students will then be able to apply this knowledge to the outside world and the chloride’s effects on sewers, ponds, fields and surrounding plants. In the winter citizens use road salt to keep the roads, sidewalks and driveways safe. Though this is beneficial to our safety it harms the plants and surrounding fields. We can be the change, and make a difference in the society by purchasing road salts that have lower levels of chloride so they are less likely dissolve into the surrounding wildlife.”*

# Reflection

## ■ Group 3: Conditions of Developmentally Appropriate Instruction

*--“To begin the inquiry, we would ask students if they know anything about global warming. Younger students might need more assistance in defining global warming, and we would provide a much simpler definition of global warming that they can easily understand. In the upper grades, we would also allow them to take the samples and measure the factors they are able to, but we would take it one step further and they would measure the wind speed and humidity as well as the air temperature. We would allow students in the upper grades to do their own research on what global warming is and what factors contribute to it, and we would do further research on any questions they had in their research.”*

# Focus Interview

- Instructional Conditions that facilitate scientific inquiry:

## 1. Responsibility and Learning Ownership:

*“it puts the responsibility on the students and they like take ownership of their own learning. Like if they are the ones being curious and then acting on that curiosity and then even further investigating into their curiosity and like asking their own questions.”*

# Focus Interview

## 2. Opportunity to Explore on Their Own:

*“It is similar to hers they just told me like what to write down in my science notebook and that was kinda it. I didn’t have a choice so I think it is kinda cool because students can explore what they want to know about it. Like for our scientific inquiry project we got that we were taking water samples but we understood that we could investigate the part that interested us the most.”*

# Focus Interview

## 3. Tension between Teacher and Students:

*“Like you said we got to choose and we are more engaged because we get to make a decision. Like with my science kids I was talking about one thing and then someone asked about a question that was different and we shifted to answering that question because it was their question and they felt like they were learning something they wanted to learn so I connected it back to what they had to learn and combined the two.”*

# Focus Interview

## 4. Applicability in Daily Life:

*“And I also think science inquiry is more applicable to life and it teaches students to be more curious about things and if you have a question then go like find out the answer.”*

# Focus Interview

## ■ Difficulty to Form a Good Research Question:

*“I know background knowledge on any of the things that we researched or wrote about and so that was challenging because before we started we had to build our own background knowledge. Because of that it was hard to build our hypothesis from the start because we didn’t really know what to ask”*

*“And we didn’t know what to find out because we didn’t really know any of the characteristics or qualities I guess.”*<sup>42</sup>

# Focus Interview

## ■ 5. Offering a Chance for Students to Struggle:

*“It’s gonna be hard to tap into all of their different background knowledges. So I think ...I really like to control and so to like kinda leave it up to them like feels hard, but then I don’t want to overstep and give them too much direction because I still want them to like be able to like do their thing and be curious.”*

# Focus Interview

*“So I guess like finding the line between what’s like enough instruction and direction and what’s like not enough.”*

*“Kinda like I want to teach them something, but I don’t want to force them to think what I’m thinking.”*

*“Right, but I also want them to do it on their own kinda.”*

# Focus Interview

## ■ 6. Challenge to Teachers:

*“And it was like our responsibility because you left it pretty open which was cool but then on the other hand it was like okay, but it was good because it was a challenge & because I have never really like taken control of my science learning ever....I don't think.”*

# Focus Interview

## ■ 7. Benefits of Experiencing Authentic Scientific Inquiry:

*-Inevitable Meaningful Cooperation:* “And so I think it was cool like we really have to figure out how we are gonna tackle this and how we are gonna figure it out and what conclusions we want to draw and everything like that....it was truly, truly up to us to work together.”

# Focus Interview

*-Inevitable Meaningful Cooperation:* “*And what she said too about teaching each other because we didn’t have any background knowledge like as we are researching we are telling each other like not only are we reading it but we are also telling someone else about it and trying to put all the pieces together as to how all of it can fit into a project”*

# Application of Scientific Inquiry

## ■ Applying into My Future Science Class:

*“I would want to implement more questioning. I want to get my students curious and I want to get them asking questions and that’s how I want to start off all of my science teaching.”*

# Results of Survey: Self-Efficacy

**(Post; N=9; one absent)**

Note: in Table, results highlighted in gray are unexpected results that need interpretations.

Questions	Agree	Neutral	Dis-agree
1. I understand what observation entails in science.	100.00	0.00	0.00
2. I will continue to find better ways to perform scientific inquiry.	100.00	0.00	0.00
3. There are multiple ways to scientific discoveries.	100.00	0.00	0.00
4. One of the scientific discoveries is to find a pattern of data collected.	88.89	0.00	11.11
5. Science is human endeavor established by society, culture, and people around the world.	66.67	33.33	0.00
6. Science is inevitably related to religion.	22.22	33.33	44.44
7. I know the steps necessary to perform scientific inquiry.	100.00	0.00	0.00
8. I will be very effective in carrying out scientific investigation.	77.78	22.22	0.00
9. If I don't feel confident about scientific investigation, it is most likely due to lack of my knowledge and skills.	44.44	22.22	33.33
10. Increased efforts in scientific inquiry performance produces change in my ability to perform scientific inquiry.	77.78	11.11	11.11

Questions	Agree	Neutral	Dis-agree
11. I am generally responsible for what I can do in scientific inquiry.	100.00	0.00	0.00
12. My ability to perform scientific inquiry is directly related to what I learned through science courses.	77.78	11.11	11.11
13. If somebody comments that I show more interest in science, it is probably due to the courses that I took in college.	55.56	33.33	11.11
14. I will find easy to explain to students why science experiments work.	66.67	33.33	0.00
15. I will typically be able to answer students' science questions.	66.67	22.22	11.11
16. Without doubts, I will have the necessary skills to perform scientific inquiry.	44.44	22.22	33.33
17. Given a choice, I prefer to invite the professor to evaluate my performance of scientific inquiry.	55.56	22.22	22.22
18. If a student has difficulty understanding a science concept, I am confident as to how to help the student understand it better.	100.00	0.00	0.00
19. When performing scientific inquiry, I will usually welcome student questions.	100.00	0.00	0.00
20. I am confident about what to do to turn students on to scientific inquiry.	88.89	11.11	0.00

**21. As the learning outcome, describe how confident you are about conducting scientific inquiry and explain how you build up your confidence about it.**

■ **Science Content Knowledge:**

*--“I am not 100% confident. To build up confidence: research and get more knowledge on the topic before teaching!!!”*

# Cont.

## ■ Pedagogical Content Knowledge (PCK):

--“I feel kind of confident in teaching students b/c they will be able to have discussions & inquire on their own if I do not know the answer.”

--“I am confident B/C I will learn as much as I can about that topic so I will be confident in that topic and the information I am giving.”

# Cont.

## ■ PCK:

--*“For the most part, I am confident with conducting scientific inquiry. The only reason why I am insecure is because I lack knowledge on scientific concepts. To build confidence I can inquire myself and learn along side my students. I can ask questions, research, and discover on my own.”*

# Cont.

## ■ Science Method Course (Inquiry-Based Science Project):

*--“I am confident extremely confident in conducting scientific inquiry for myself and my students! I built up confidence in this through this course and project.”*

*--“I am pretty confident after this course, though I still feel I need to grow in teaching science by teaching more lessons.”*

*--“I feel that my confidence was built up through going through the process of inquiry multiple times.”*

*--“I am very confident due to my TCH 257 course”*

# Cont.

## ■ Science Teaching Experience (in Clinical):

-- *“I am very confident! A lot of that came from the lesson we created and taught in clinical.”*

-- *“My confidence will continue to grow in science teaching with experience.”*

-- *“I feel confident about my ability to conduct scientific inquiry. Having the practice in my science classrooms helped a lot.”*

# Discussion

- Preservice teachers diagnosed what is lacking in their ability to conduct scientific inquiry and understood the complexity of creating scientific knowledge through authentic scientific research experiences and learning on themselves.
  - They realized that they had (a) lack of scientific knowledge and science background, (b) lack of scientific research experience, and (c) lack of scientific knowledge in real context.
  - They went through confusion and frustration during scientific research.
  - They gained a meaningful learning through scientific inquiry – asking question, observation, data collection, analysis, experimentation, etc.
  - They never heard of the concept of scientific inquiry until junior year in college.
  - They understood the goal of scientific inquiry, “creating new knowledge.”

# Cont.

- **Preservice teachers developed the ideas of instructional conditions that promote their understanding of scientific inquiry.**
  - They came up with plans to apply what was learned through scientific inquiry to their surroundings, e.g., how chloride affects on sewers, ponds, plants, etc.
  - They planned the conditions of developmentally appropriate instructions including (a) responsibility and learning ownership, (b) opportunity to explore on their own, (c) handling tension between teacher and students, (d) application in daily life, (e) offering a chance for students to struggle, and (f) being aware of challenges and benefits to teachers and students.

# Cont.

- Preservice teachers developed the high level of their self-efficacy in teaching science through understanding of and conducting scientific inquiry. However, they were still unsure about the following issues (see Survey Result Table).
  - They were not confident about science as human endeavor. It is, in part, because they did not get a chance to extensively learn about the Nature of Science topic.
  - They did not agree that science is inevitably related to religion – science is in separate dimension.
  - They did not think that ‘lack of knowledge’ is the major reason about their low level of confidence in scientific inquiry though they admit it as one factor.
  - They partially agree that their interest in science is due to the college courses they took.

# Cont.

- Preservice teachers picked the following factors as the vehicle to build up their confidence about scientific inquiry
  - Science Content knowledge
  - Pedagogical Knowledge
  - Science Method Course (Inquiry-base Science Project)
  - Science Teaching Experience (in Clinical)
  - Meaningful Cooperation in a Group

# Recommendations for Improving Scientific Inquiry

## Factors to Build a Confidence

<b>Understanding Complexity</b>	<b>Instructional Conditions of Teaching</b>
1. Forming a good research question is not easy.	<p>Confidence builds on several factors:</p> <ol style="list-style-type: none"><li>1. Scientific knowledge and background</li><li>2. Pedagogical Knowledge</li><li>3. Science Method Course (Inquiry-base Science Project)</li><li>4. Science Teaching Experience (in Clinical)</li><li>5. Meaningful Cooperation in a Group</li></ol>
2. Analyzing data not always go as expected. There are frustration and confusion during the process.	
3. It requires multiple sources of data to interpret (e.g., EPA Standards).	
4. It requires scientific knowledge in real context and scientific research experiences.	

# Implications

- Purpose of TCH 247 Scientific Inquiry:
  - help preservice teachers teach science in a meaningful way.
- Research Experience of Scientific Inquiry:
  - Increased understanding of the complexity of it
  - developing an idea of instructional conditions that facility the scientific inquiry.
- Ways to Increase Self-Efficacy about Scientific Inquiry:
  - Scientific knowledge and background
  - Pedagogical Knowledge
  - Science Method Course (Inquiry-base Science Project)
  - Science Teaching Experience (in Clinical)
  - Meaningful Cooperation in a Group

# Conclusion

- TCH 247 Scientific Inquiry Course needs to incorporate with:
  - Research Experience of Scientific Inquiry.
  - Scientific knowledge and background
  - Pedagogical Knowledge
  - Inquiry-base Science Project
  - Meaningful Cooperation in a Group

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