Development and Implementation of a Guided-Inquiry Laboratory Structure for an Introductory Chemistry Course




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Value of Verification and Inquiry Approaches

Value - Verification

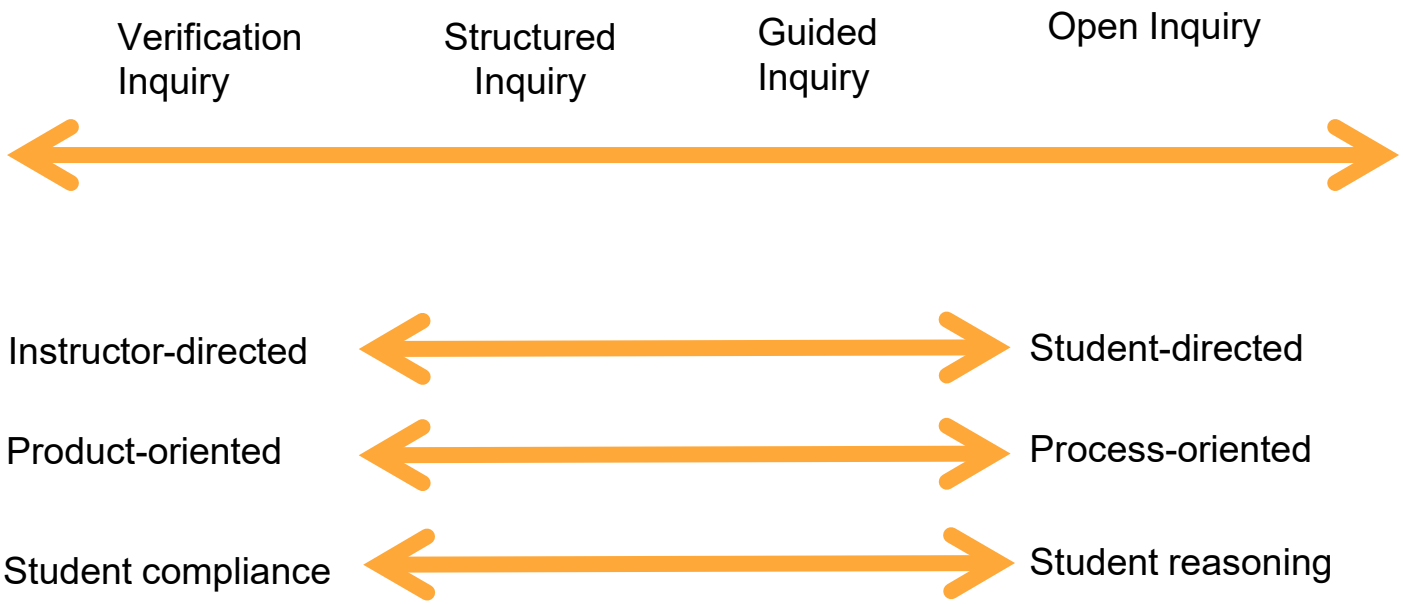
- Established curriculum and assessments
- Reinforce lecture content
- Practice specific techniques
- All students complete the same work (within the laboratory)
- Little guidance needed for new teaching assistants

Value - Inquiry

- Mirrors the work of scientists
- Supports student problematizing, questioning and hypothesis generation to evaluating and communicating results
- Diversity in student work – better aligned with their understanding

Akuma & Callaghan, 2019; Baran & Sozbilir, 2018; Barrie et al., 2015; Carmel et al., 2019; Chinn & Hmelo-Silver, 2002; Domin, 1999; Esparza et al., 2020; Furtak et al., 2012; Grooms et al., 2014; Hofstein & Lunetta, 2004; Kirschner et al., 2006; Liu et al., 2010; Minner et al., 2010; Mistry et al., 2016; Wheeler et al., 2019; Tsaparlis & Gorezi, 2007

Spectrum of Inquiry Scaffolding



See also: Blanchard et al., 2010; Brownell & Kloser, 2015; Buck et al., 2008; Schwab, 1962; Herron, 1971

Student Motivation for Inquiry Approaches

- Students can be resistant to active-based forms of instruction
- Difficulties in persuading students to reflect on their experiences and findings
- Different motivational profiles of students (values, self-efficacy, cost) in taking Introductory Chemistry courses
- Importance of avoiding deficit view of students' motivation – issues may be inherent within the course structure ("Weeder courses")

Akuma & Callaghan, 2019; Cooper et al., 2017; Fong et al., 2021; Lee et al., 2022; White et al., 2021

Research Questions

1. What are **student conceptual outcomes** of a verification and a guided-inquiry Introductory Chemistry laboratory? (Spring/Fall 2018 Data)

2. What are **student motivation outcomes** of a verification and a guided-inquiry Introductory Chemistry laboratory? (Spring 2018 Data)

Method

- Mixed Method Study – Majority Quantitative with Nested Qualitative Design/Situationalist Perspective

  (Creswell et al., 2004; Onwuegbuzie & Leech, 2005)

- Pre/Post Comparison Study for Two Semesters (Spring/Fall 2018)
  -Eight pre/post conceptual assessment items scored 1-5 with constructivist Knowledge Integration framework (Linn & Eylon, 2011; RQ1)
  -Scored independently by two coders with disagreements then resolved
  -General linear models with repeated measures. Significance at <.05

  -Short post-course student survey (RQ2) – what students enjoyed about the lab, what they would change, and their role in the lab. Responses coded for five EVT features – Expectancy, Intrinsic, Attainment, Utility, and Cost

- Participants: 60% Female, 47% Hispanic or Latino/a, 70% Freshmen/Soph.

Two Laboratory Approaches

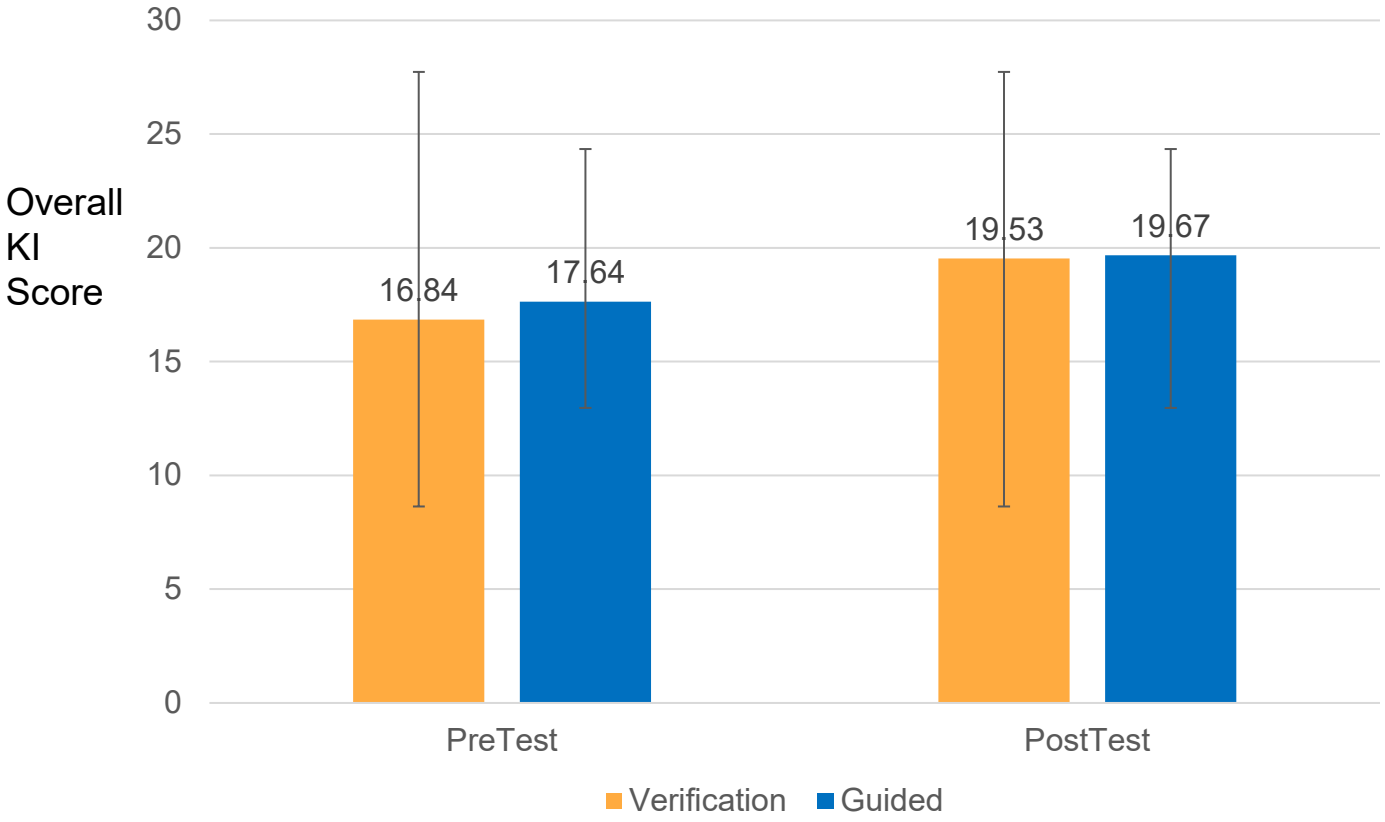
Verification Laboratory

- 14 laboratories (Two training laboratories, eight experiments and four study guides)
- Laboratory focus: Demonstrating common laboratory skills and procedures
- Laboratories are connected to lecture

Guided-Inquiry Laboratory

- 14 laboratories (Two training and orientation laboratories, and four three week investigations involving planning, experiment, and presentation days)
- Laboratory focus: Providing authentic experience in applying the scientific method
- Laboratories are connected via a zoo context and science practices

Overall Findings – RQ1 (Spring 2018; n = 293)



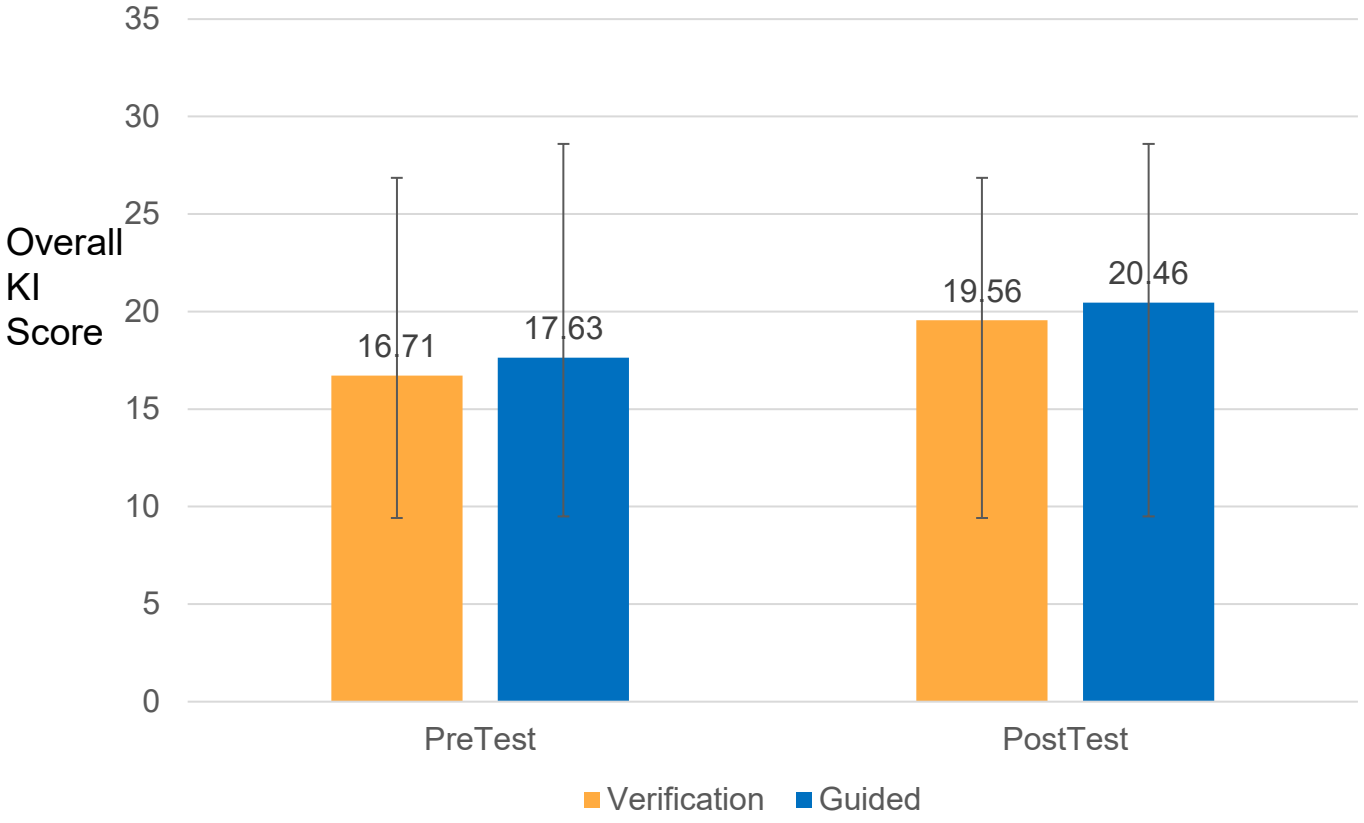
No significant pre/post differences between treatments (p = 0.295)

Effect Size* Verification (n = 162) = 0.59 (Medium Effect)

Effect Size* Guided (n = 131) = 0.56 (Medium Effect)

*Effect Size – Cohen's d (Uses mean, SD, and sample size) - <.029 (Low); 0.3-0.59 (Medium); >0.6 (Large)

Overall Findings – RQ1 (Fall 2018; n = 369)



No significant pre/post differences by treatment (p = 0.964)

Effect Size Verification (n = 206) = 0.68 (Large Effect)

Effect Size Guided (n = 163) = 0.72 (Large Effect)

Examples of Student Comments – RQ2

- **Expectancy (Of instructor)**

  “give us guidance, but not the answers during the lab. As well as steer us towards where to find the answer and how to apply it to our questions.”

  Male Hispanic Freshman Student, Guided-Inquiry

- **Expectancy (Of ability)**

  “The quizzes are also very difficult. We are students who have zero background in chemistry and yet you except [sic] us to know how to remember how to name every formula.”

  Female Hispanic Freshman Student, Verification-Inquiry

- **Expectancy (Of instructor and ability)**

  “I would change the amount of help that was provided by the instructor. I feel that these concepts were a little hard to grasp for non chemistry majors.”

  Male Hispanic Sophomore Student, Guided-Inquiry

Intrinsic (Interest/Enjoyment)

“i enjoyed the experiments, and how interesting they were i felt i could learn something new about chemicals everyday”

Female White Sophomore Student, Verification-Inquiry

“I enjoyed creating my own laboratory experiments it cause me to really think what I was doing rather than go through the motions.”

Male Hispanic Freshman Student, Guided-Inquiry

“I did not like the fact that we had to create our own labs. I like using a lab manual more.”

Male White Sophomore Student, Guided-Inquiry

Attainment value (Identity): Limited comments in the data

“i wish there were a little more guidelines to follow instead of just handing us a template and saying construct a lab from this; however i have always been one to like guidelines rather than basing everything off of creativity.”

Female White Freshman Student, Guided-Inquiry

Utility Value (Useful to one's current or future plans):

"I enjoyed the different topics in lab and how this class pushed me from my comfort zone. I don't like chemistry but I feel like I learned important things I will use in the future."

Female Hispanic Sophomore Student, Guided-Inquiry

"Following rules and procedures, completing assignments on time"

White Male Senior Student, Guided-Inquiry

"wear lab clothes at all time. Follow direction."

Asian Female Sophomore Student, Verification-Inquiry

Cost (Effort, opportunity, emotions)

“The writing essays didn’t seem to relate to what we were doing in class”

Male Hispanic Freshman, Verification-Inquiry

“NO MORE QUIZZES WE ALREADY HAVE ENOUGH FROM LECTURE!”

Female Hispanic Sophomore, Verification-Inquiry

“More structure and help. A guessing game about experiments does not create a good learning environment, it fosters irritation and bitterness against an area of study.”

White Freshman Student (Didn’t Share Gender), Guided-Inquiry

Discussion

- Similar conceptual outcomes by laboratory type. Encouraging for a new laboratory structure with a new pedagogical approach.
- Valued features across both laboratory structures:
  -Getting to experiment – “hands-on” and guidance from instructors
- Student frustration when perceiving insufficient instructor guidance
- Specific to guided inquiry laboratory: Agency to be creative in designing their own labs – “minds-on” (Yannier et al., 2021)
- Zoo context is rarely discussed by students (Five student comments – Spring 2018 data) – Context important, but not central to laboratory enjoyment

Akuma & Callaghan, 2019; Hernandez et al., 2021; Kirschner et al., 2006; Yannier et al., 2021

Implications for Laboratory Courses

- *Questioning what the purpose of laboratory is and for who?*
  Challenging with a diverse group of non-majors with diverse identities/interests – Teaching to the middle

- *Questioning how we prepare laboratory instructors?*
  The goal is obviously to challenge, but not frustrate students. Inquiry can be challenging, even for experienced instructors.

- *Questioning the exact role of context within laboratories?*
  Many efforts are heavily focused on engaging contexts, but they possibly take a backseat within the process of completing a laboratory.

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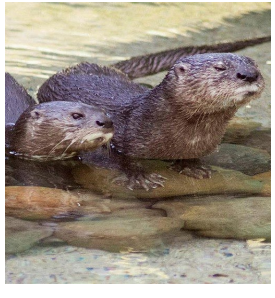

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