





Implementing Innovative Constructivism: An Architected Approach to Enhancing STEM Education

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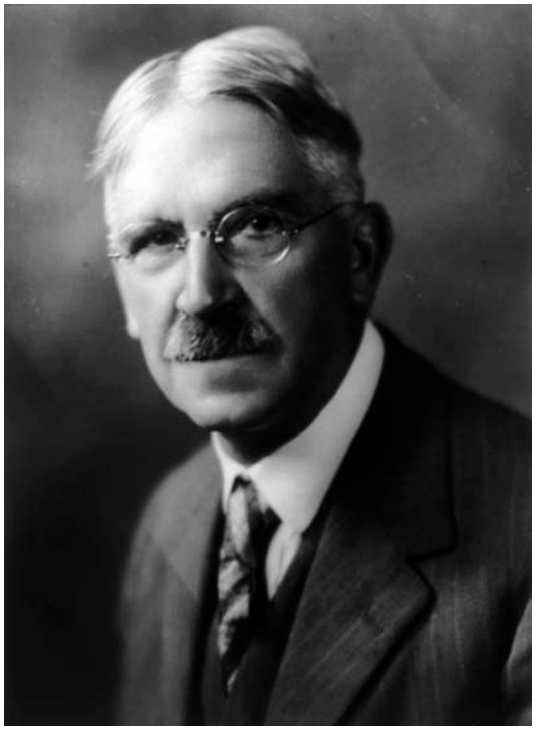
Major Thesis

Constructivist pedagogical approaches are widely regarded as potentially beneficial in many contexts, including the broad range of Department of Defense educational environments. However, many implementations of these approaches are difficult to realize both for the instructional personnel and for the target populations of the education who are typically familiar with the direct instruction method and uncomfortable with any other approach. The primary author has developed, tested and employed a new approach that provides a framework to assist both instructor and learner in benefiting from constructivism. This addition would be productively adopted by the various levels of DoD education and could provide a benefit to the Warfighter in reaching the ultimate goal of that education.

Constructivism

- Advocates facilitating learning rather than the direct instruction method
- Some see the Socratic method as a precursor variant of Constructivism
- John Dewey seen as progenitor in the early 20th century
- Jean Piaget studied the way children learn
  - Stimulated advances in the understanding of constructivist techniques
- Roger Bybee established a mantra for constructivist approaches known as the 5 E's
- Critics say learners are lost, need structure and often miss the point

Some Founders of Constructivism



John Dewey



Jean Piaget



Roger Bybee

Roger Bybee and the "5 Es"

- NIH/Biological Sciences Curriculum Study (BSCS) report
- The paper explained the 5 Es of science instruction
  - Engage - help them become engaged in a new concept through the use of short activities
  - Explore - provide students with a common base of activities
  - within which current concepts can be learned
  - Explain - focus students' attention on a particular aspect of their engagement and exploration experiences
  - Elaborate - challenge and extend students' conceptual understanding and skills
  - Evaluate - encourage students to assess their understanding

Manifesting Engagement

- Engagement by lower SES high school students was achieved using a 4 x 8 ft. "Zombie Apocalypse City"
- A varied ecological environment was created
  - Supported state standards for Biology and Environmental Science



Engagement Technique

- Zombies are an example of an engagement environment that is well-known to students in the early 21st Century
- It is an ephemeral topic and should not be taken as a standard, *e.g.* DoD personnel might react more enthusiastically to an Afghan Village
- The instructor or curriculum director should tailor
- Necessary elements are
  - Compelling and interesting setting
  - Environmental diversity supporting many options that are topic specific (in this case, Biological and Environmental Science)
  - Must allow for credible and simulatable scenarios

Photosynthesis Model via Legos®



- Smaller models can be used to allow students to explore specific concepts
- Model of photosynthesis (left)
  - Water molecules (blue and red, bottom right)
  - Split by the user
  - Placed in the light reaction (white)
  - The hydrogen (red) release s ATP
  - Causes formation of a sugar molecule (black and blue, bottom middle)

An Effective Communications Paradigm

- Using the model as a backdrop, a cross disciplinary communications skill set was taught following the lead of Jeremy Porter
- Set emphasized: WHAT, HOW, WHY, WHEN and WHERE
- Students were briefed as to looking out for these and to use this format
- The ideas are then synthesized to create a concept to develop skills extensible to other classes and to their lives

The Construct

Questions

- Qualifying questions
- WHAT questions
- HOW questions
- WHY questions

Investigation

- Observations
- Claim
- Evidence
- Reasoning



Qualifying Questions

- **When to use**
  - These questions are asked when more information is needed about a person, place or thing (noun) such as its description (adjective) and/or the function (verb)
- **How to use**
  - Is/Are…?
  - Do(es)…?
  - Can…?
  - How many…?
  - How much…?
- *Example: Can this gear fit in this motor?*

Observations

- These questions are used during observations to gain an understanding of what is being observed

What Questions

- **When to use**
  - These questions are asked when the person, place or thing (noun) is unknown or when the **part** of a process (verb) or function is unknown
- **How to use**
  - What is/are…?
  - What do(es)…?
  - What can…?
  - What will…?
- *Example: What does this gear do for the motor?*

Claims

- A claim or claims can be generated for the answers to these types of questions
- A statement or judgment can be generated from the answer or answers to these types of questions



How Questions

- **When to use**
  - These questions are asked when the **whole** process (verb) or function of some event (noun) is unknown
- **How to use**
  - How does…?
  - How is/are…?
- *Example: How does a transmission turn the crank shaft?*

Evidence

- Once the WHATs are identified and confirmed, a pattern or an order of some process can then be understood by the observer
- The comprehension of this process allows the observer to give more detail in their report



Why Questions

- **When to use**
  - These questions are asked when the **cause or the source** of an event is unknown
- **How to use**
  - Why do(es)…?
  - Why is/are…?
- *Example: Why does the car start up when I turn the key?*

Reasoning

- The answers to Why questions connect one function with another connecting idea or connect concepts to each other
- Provides a diagnostic understanding of the information



Information Flow

- Content must be connected or related throughout the lessons, unit, term, and course
- Students need to confirm their understanding of experiences with isolated packets of information
- Students are observed to have varying degrees of difficulty with mental transition
- Leads to difficulties getting the students to put the information together into a concept
- The transition from discrete packets of information to developing and applying concepts is difficult

Evaluation

- Students were evaluated through assessment rubrics
  - Multiple-choice testing was not implemented
  - Formal assessment of student skills was not employed
- Rubric matrix language had to be written prescribing
  - WHAT they needed to say
  - HOW they needed to say it
  - WHY it should have been said
- The assessments had to include
  - Claim
  - Evidence
  - Reasoning

Anecdotal Observations

- Many students exhibited
  - Increased interest in science
  - More enthusiasm for school
  - Improved communication skills
  - Initiative in creating and manipulating data
- Work samples showed dramatic interest in scientific methods and advances sophistication in their understanding
- While the majority improved, alas, a few students who had histories of low achievement remained resistant to this approach as well, but their work product improved

Data Analysis

- These results support meeting the Primary Author's goals:
  - improved communication skills
  - scientific method understanding
  - interest in academic pursuits increased
- Questions seven and eight seem to indicate that the method used in this class was not so different as to be disruptive
- Last four questions reflect student increased interest in science and college and recommending this class to others
- The highest correlation found was that those who preferred analysis to memory were the most likely to prefer this method of teaching: $r = 0.46$

DoD Implications

- Junior NCO's and Commissioned Officers will make career choices based on future prospects
- The need for "thinking" military leadership is critical
- This work has shown a functioning example of how the constructivist theory can be implemented
- It provides the recipients of the education with a framework to assist transition into a constructivist classes
- Insights gained from this communication process should be applicable to other communication efforts.
- The "5 E's" may make a critical difference in thinking
- Critical thinking and meta-cognitive skills can be taught and have been shown to produce beneficial results.

Post Secondary School Environment

- Many of the military recruits come straight from high school
- They need to pursue collegiate education, even NCOs
- DoD is also responsible for the academies and ROTC
- Significant numbers of active duty personnel seek degrees
- Lessons learned from this paper's implementation of constructivism could be fostered in a number of ways
- Operational commitments mandate these educational activities need to be designed to not disrupt the critical military duties and skills training

Conclusions

- Education is increasingly vital to the defense posture of the nation
- Traditional form of education has limitations
- A constructivist approach
  - Is easily transferable to other journeymen teachers/instructors
  - Does not appear to be dependent on a charismatic "hero teacher"
  - Can significantly increase learner understanding of concepts
- Newly emerging computer tools, such as conversational avatars, could enhance this method and should be the focus of follow-on research efforts

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Data from Survey

Early and Constrained Results

Rating	-2.0 Strongly Disagree	-1.0 Disagree	0.0 No Opinion	+1.0 Agree	+2.0 Strongly Agree	Arithmetic Mean
Science has always been my favorite subject.	4 7.3 %	19 34.5 %	10 18.2 %	16 29.1 %	6 10.9 %	0.0
I have always gotten good grades in science.	2 3.6 %	19 34.5 %	8 14.5 %	23 41.8 %	3 5.5 %	0.1
I have always wanted a career in science.	2 3.6 %	5 9.1 %	10 18.2 %	22 40.0 %	16 29.1 %	0.8
My parents are interested in science.	1 1.8 %	6 10.9 %	24 43.6 %	14 25.5 %	10 18.2 %	0.5
I often watch TV shows or read books about science.	3 5.5 %	17 30.9 %	7 12.7 %	17 30.9 %	11 20.0 %	0.3
Biology has always been my favorite science.	4 7.3 %	8 14.5 %	12 21.8 %	15 27.3 %	16 29.1 %	0.6
Previous science classes have emphasized discovery and research.	2 3.6 %	25 45.5 %	13 23.6 %	11 20.0 %	4 7.3 %	-0.2
This biology course is different in the way it teaches science.	22 40.0 %	20 36.4 %	5 9.1 %	3 5.5 %	5 9.1 %	-0.9
I like discovering things on my own.	11 20.0 %	22 40.0 %	16 29.1 %	5 9.1 %	1 1.8 %	-0.7
It helps me discover things if I have some guidance on how to do it.	6 10.9 %	21 38.2 %	16 29.1 %	6 10.9 %	6 10.9 %	-0.3

Early and Constrained Results, cont.

Rating	-2.0 Strongly Disagree	-1.0 Disagree	0.0 No Opinion	+1.0 Agree	+2.0 Strongly Agree	Arithmetic Mean
Having the model of Riverton helps me think through the issues.	4 7.3 %	15 27.3 %	13 23.6 %	12 21.8 %	11 20.0 %	0.2
I find the fantasy setting makes the issues more interesting.	2 3.6 %	19 34.5 %	11 20.0 %	10 18.2 %	13 23.6 %	0.2
Learning how to analyze is more important than memorizing facts.	3 5.5 %	20 36.4 %	18 32.7 %	9 16.4 %	5 9.1 %	-0.1
I use the techniques I learn here in my everyday life.	1 1.8 %	7 12.7 %	20 36.4 %	12 21.8 %	15 27.3 %	0.6
This class has made me appreciate science more.	0 0.0 %	15 27.3 %	12 21.8 %	15 27.3 %	13 23.6 %	0.5
I am now more interested in taking other science classes.	2 3.6 %	8 14.5 %	12 21.8 %	21 38.2 %	12 21.8 %	0.6
This class has encouraged me to go to college.	1 1.8 %	8 14.5 %	16 29.1 %	17 30.9 %	13 23.6 %	0.6
I would recommend that my friends took this class.	5 9.1 %	6 10.9 %	10 18.2 %	11 20.0 %	23 41.8 %	0.7
I am now more likely to pursue a science career.	2 3.6 %	5 9.1 %	10 18.2 %	15 27.3 %	23 41.8 %	0.9
Other classes should use this approach to teaching.	6 10.9 %	7 12.7 %	14 25.5 %	8 14.5 %	20 36.4 %	0.5