Innovative Methods of Teaching & Learning Science and Engineering in Middle Schools

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The 3th International Conference on Education and Information Systems: Technologies and Applications
Paper available as **E898HR.pdf** on the CD
Electronics Proceedings
Printed Proceedings Vol. 1, pp. **174-178**

EPCOT

EPCOT continued . . .

Challenges

1. **The needs of young adolescents are not met by textbook-based direct instruction of teachers**

Recent **TIMSS** (Trends in International Mathematics and Science Study) results, **measuring** Grade 4 and 8 students' **math and science learning**, showed US 4th graders' performance in mathematics was lower in 2003 compared to 1995 (due to lower average science achievement).

2. **Several students find science, technology, engineering, and mathematics (STEM) irrelevant**

Recent **PISA** (Programme for International Student Assessment) results, **measuring** Grade 10 students' **application** of math and science **to real-life** contexts, showed US ranked 24th out of 29 OECD nations in mathematics literacy and problem solving.

Challenges continued . . .

3. **How do we identify the most appropriate material to teach from the National Curriculum or *Content Standards*, and teach them effectively and efficiently?**

The poor performance may not be only be because of a **lack of fit** between the international tests and the local curriculum.

4. **How could we measure students' performance vis-à-vis *The Standards* during classroom instruction?**

Gathering such information would greatly help teachers and schools **meet federal mandates** and accountability requirements.

Challenges continued . . .

5. **How could we support students' preference for *learning by doing*?**

Hands-on **inquiry learning without domain knowledge** merely entertains students and results in their inadequate conceptual understanding?

6. **Many resource-deprived students reach schools with limited cognitive skills and consequently less motivated.**

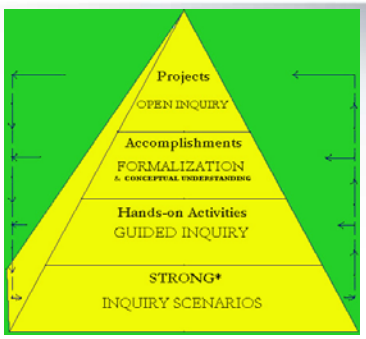
Wilson [15] observed that **direct instruction to impart domain knowledge** in sterile learning environments left students unenlightened and unable to see its real-world relevance.

Inquiry or Direct Instruction?

To cope with this **dilemma**, we describe **a framework** that seeks to immerse all students in a progression of guided inquiry hands-on activities to facilitate their conceptual STEM understanding, starting with **STRONG*** and proceeding to less guided forms of inquiry learning.

* STRONG is an acronym for STRuctured-scenario ONline Games

Our Conceptual Framework – The STRONG Model



Why STRONG?

STR**uctured-scenario **ON**line **G**ames* are modular, self-contained, easily accessible, multi-player, ***online interactive learning environments, designed to **motivate**, direct, facilitate, and assess middle-school students' conceptual science, technology, engineering, and mathematics (**STEM**) **learning through deliberate reflection**.

Typical STRONG Inquiry Scenario

The website

http://www.GamesToLearn.us

illustrates a typical inquiry scenario used in STRONG.

When a student clicks on the Game Mock-Up, as the game downloads, they are **directed to a PreTest**.

www.GamesToLearn.us

Instructions Students Hear for PreTest

It is important for you to do your best because your teachers and the game designers want to know how well you understand the concept "electrical circuits require a **complete path** through which an electrical current can pass."

PreTest Questions

Will the light bulbs in the circuits below light or not?
Predict Y (Yes) or N (No)

Circuit A | Circuit B | Circuit C | Circuit D

PreTest Questions

Will the light bulbs in the circuits below light or not?
Predict Y (Yes) or N (No)

Circuit E | Circuit F | Circuit G | Circuit H | Circuit I

Hands-on Assessment Kit

Hands-on Assessment Challenge

Can you make the **light bulb** stay **lighted** with only one hand **and not** have it **burn your fingers** at all?

Cognitive Dissonance

STOP → **REFLECT** → **THINK** → **ACT**

STRONG Prototype

Game Mock-Up

With a **student generated** inquiry scenario
to **contextualize** learning

Circuit Construction Java Simulation

The PhET Team's Circuit Simulation
Physics Education Technology Project
University of Colorado
www.colorado.edu/physics/phet/

Students' Reflection-In-Action

Illustrating middle schools students' inherent thinking styles

Sample Worked Example

To guide students gently into **thinking and testing** their **ideas**, worked examples like this are embedded in STRONG.

Sample Worked Example

Sample Students' Work

As students experiment and learn with the simulation and subsequent hands-on activities, their **paired collaborative problem solving** and **deliberate reflection** facilitated through STRONG helps them design and **contribute** their ideas like this to our knowledge base.

These designs and more will be made available in the chat area to foster an online learning community, with the enterprising **students volunteering to** take a **lead** for facilitating meaningful discussions.

STRONG Potential

- **Motivate** more students to engage with STEM learning
- Collect individual student data **real-time** and compile a meaningful document for teachers to address students' **preconceptions** and also learn what students already know.
- **Improve learners' domain knowledge** prior to and during active inquiry learning-by-doing
- Facilitate **outcomes-oriented** and performance-driven instruction and assessment

Assessment in STRONG

Assessing student learning is a big challenge.

The recently published *Systems for State Science Assessments* recommends over 18 approaches to assess student understanding.

STRONG inherently enables numerous approaches, including questioning, self-assessments, problem-solving, peer-assessments, and more.

Assessment Approaches

Different assessment approaches that states might incorporate

Observations: Watching work in progress shows student attitudes, communication and process skills.

Questioning: Questioning can check the depth of student understanding, shown in other assessments, show attitudes. Open questions can show ability to apply knowledge to new situations.

Presentations: Oral or written presentations allow students to show their ability to communicate scientifically and their understanding and application of scientific knowledge.

Fieldwork: Fieldwork allows students to show planning, investigating and data-collection skills and the application of their scientific knowledge.

Self-assessments: Students reflect on their learning, listing what they know and their concerns.

Modelling/simulations: Modelling activities allow students to clarify and show the depth of their understanding and to communicate scientifically.

Student portfolios: Samples of work selected by students to show the range of their understanding and their progress over time.

Problem-solving: Problem-solving activities can show students' investigating and analysing skills and ability to apply scientific knowledge.

Concept mapping: Identifying and linking key words can show students' level of understanding of a topic.

Written Tests: Tests can show the extent of students' scientific knowledge and ability to apply it.

Research projects: Students working on projects can show planning, organising and investigative skills. Project products can show analysing, interpreting and communication skills.

Practical investigations: In practical activities students show investigation, research, prediction and manipulative skills. Reports can show skill in communication and daring conclusions.

Practical tests: Practical tests can provide information on students' process skills and their ability to apply their scientific knowledge.

Peer-assessments: Peer-assessments can show students' ability to communicate to an audience.

Creative writing: Creative writing can show students' depth understanding, application of scientific knowledge and communication skills.

Student profiles: Samples of student work annotated with teacher comments on outcomes demonstrated can show progress over time.

Bundling activities: Collecting, analysing and organising activities can assist student understanding and show process skills.

Drawing: Drawing and labeling can show students' depth of understanding and communication skills.

From

Systems for State Science Assessment (**2005**)

p. 2-15

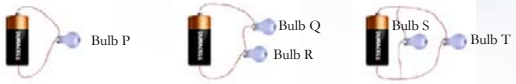
Embedded Assessments in STRONG

When students are ready to test their understanding of a concept, say, "electrical circuits require a complete loop through which an electrical current can pass," they answer **six** questions that promote their **higher order thinking**.

Their performance in these six questions, as a **team**, determine their **score** at the end of the game.

Sample Scored Question in STRONG

During one of Peggy and Cassandra's attempts at their signal, they connected the following three circuits.



Sample Scored Question in STRONG . . .

Rank the four responses below in the correct order.

A. The wires are warm, and the bulbs P, Q, & R are of the same brightness
B. The wires are warm, and the bulbs P, S, & T are of the same brightness
C. The wires are cold, and the bulbs P, Q, & R are of the same brightness
D. The wires are cold, and the bulbs P, S, & T are of the same brightness

MY **confidence multiplier** is

10 9 8 7 6 5 4 3 2 1

I am 100% sure **I am guessing**

Finally, some PostTest Questions

Will the light bulbs in the circuits below light or not?
Predict Y (Yes) or N (No)

Circuit A **Circuit B** **Circuit C** **Circuit D**

PostTest Questions

Will the light bulbs in the circuits below light or not?
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Circuit E **Circuit F** **Circuit G** **Circuit H** **Circuit I**

In Conclusion

Learning math and science using STRONG would help several **students**

- Cross an important TIPPING POINT to foster meaningful self-organized learning
- Develop their critical processing skills and **teachers** teaching math and science
- Facilitate more HANDS-ON inquiry learning
- Assess students understanding vis-à-vis the *Standards*

Next Steps

- What you have seen thus far is my work with middle-school students last year, with minor modifications that they recommended.
- Clearly, our development work in ongoing and part of our larger design experiment.
- In the coming months, we hope to complete building our prototype, with all its bells and whistles, and look forward to working with more students.
- Based on their feedback and responses, we would modify our subsequent designs.
- These eventually, will lead to more formal studies of learning and achievement in middle schools.

Questions?