Improving Classroom Instruction of Stoichiometry Through Reducing Students' Cognitive Load: A Literature Review

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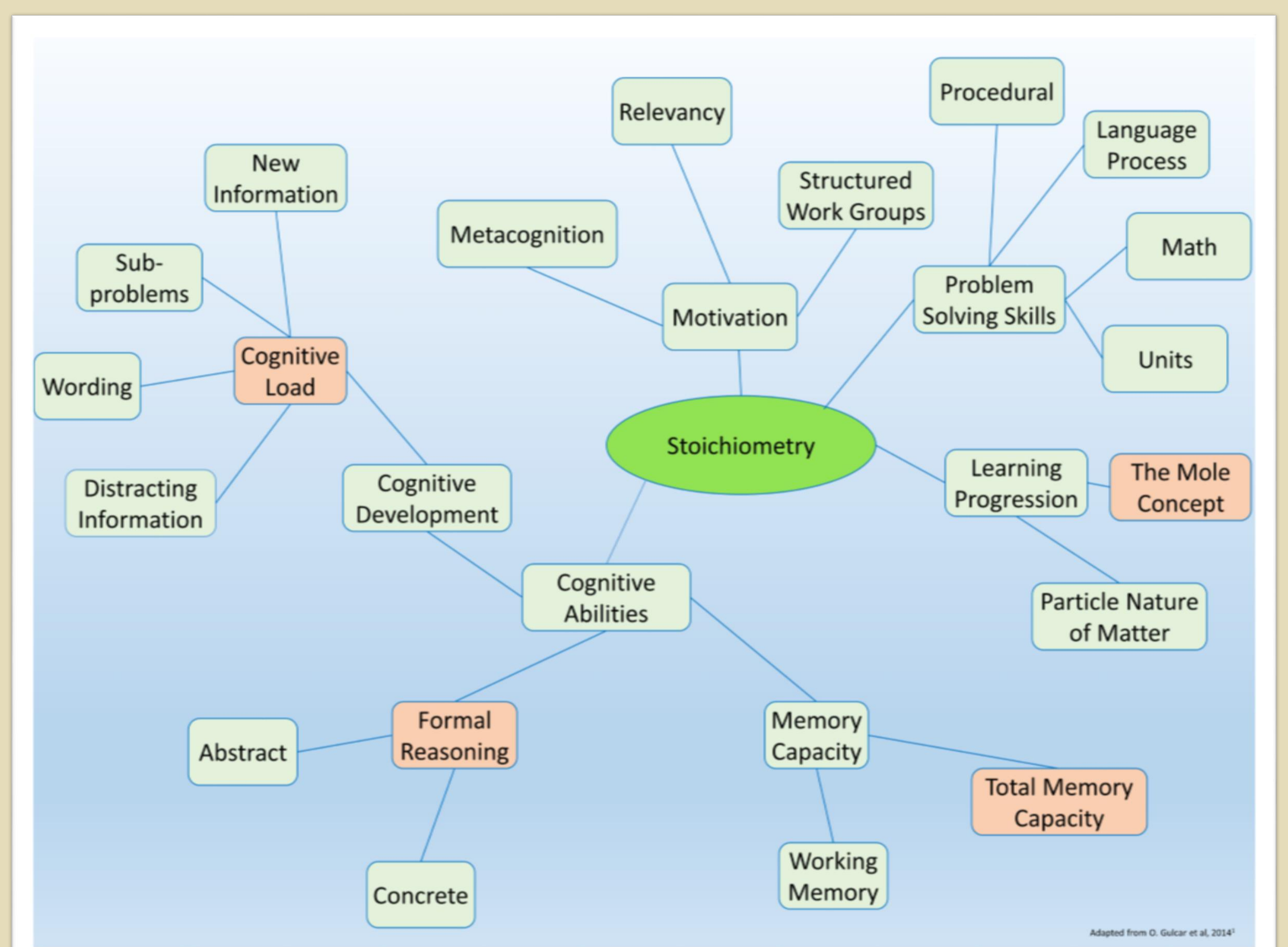
Introduction:

- Cognitive Load describes the amount of mental effort required by the brain to do something. Many things can contribute to an experienced Cognitive Load including the presence of new information, the number of variables and sub-problems present, as well as the presence of unrelated, preoccupying issues or information.[1,5]
- As a student ages through his/her teen years, they become increasingly capable of Abstract Thought and, combining with an already well-established Concrete Thought, allow for the development of Formal Reasoning. Several studies indicate this development is dependent on specific training.[1,3,5,6]
- Total Memory Capacity includes both what the student can keep track of at a particular moment (Working Memory) and the student's ability to store information in and transfer information from long-term memory (Memory Capacity).[1]
- The Mole Concept centers around the premise that scientists typically do not deal with single atoms and molecules in the laboratory and, therefore, do not measure masses with Atomic Mass Units (AMU). Rather, scientists deal with groups of things (atoms, molecules, or formula units) that allow for measuring masses in grams.
- Equivalency: 1 mole = 6.022×10^{23} things = gram formula mass of a substance



Scenario:

- Student: "But, I don't understand this Mole Concept thing. What's the point?"
- Teacher: "Okay, you know what, don't worry about it. Just focus on the math; that's the important part."

Missed Development Opportunity

Working Premises:

- Allowing student to fall back to more Concrete Thought with math-based processes ignores student need to continue developing Abstract Thought.
- Easing student Cognitive Load will facilitate cognitive development, improve learning, and provide a more positive view of self and learning experience.

Objectives:

- Identify challenges in students' learning that act as barriers to achieving proficiency with the entire process.
- Identify teaching strategies that will lessen students' experienced Cognitive Load.

Stoichiometry:

- A key concept in Chemistry; it is an interdisciplinary network of learnings as well as a central element in allowing for analytical application of many different concepts (ie solution stoichiometry, ideal gas law stoichiometry, REDOX reactions).
  Basic Stoichiometric Process: see Figure 1.
- Typically requires an integration of abstract and concrete concepts[1]
- Requiring a broad integration of knowledge and skills for implementation, acquiring proficiency with stoichiometry can represent a steep learning curve, challenging a student's Cognitive Load.
- Particular roadblocks to students' progress involve: Formal Reasoning, understanding of Mole Concept, Total Memory Capacity, and ability to handle Cognitive Load.

Figure 1: Basic Stoichiometric Process

What mass of carbon dioxide will be yielded from the combustion of 2.5g propane?

Balanced Chemical Equation: $C_3H_{8\,(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2\,(g)} + 4H_2O_{(g)}$

Calculate formula mass for C_3H_8: $3 \text{ mol C} \left(\frac{12.011\ g\ C}{1\ mol\ C}\right) + 8 \text{ mol H} \left(\frac{1.00794\ g\ H}{1\ mol\ H}\right) = 44.09652 \text{ g/mol } C_3H_8$

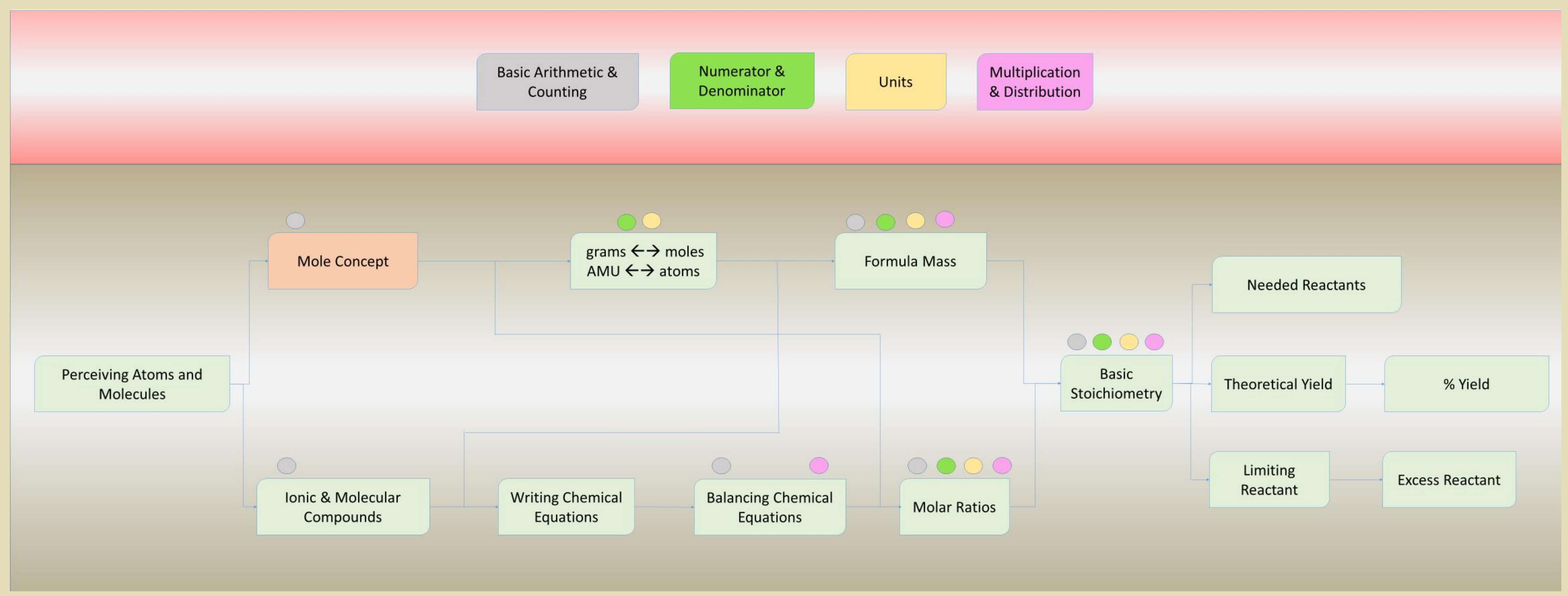
Calculate formula mass for CO_2: $1 \text{ mol C} \left(\frac{12.011\ g\ C}{1\ mol\ C}\right) + 2 \text{ mol O} \left(\frac{15.9994\ g\ O}{1\ mol\ H}\right) = 44.0098 \text{ g/mol } C_3H_8$

Calculate theoretical yield of CO_2 from given C_3H_8:

$$2.5 \text{ g } C_3H_8 \left(\frac{1\ mol\ C_3H_8}{44.09652\ C_3H_8}\right)\left(\frac{3\ mol\ CO_2}{1\ mol\ C_3H_8}\right)\left(\frac{44.0098\ g\ CO_2}{1\ mol\ CO_2}\right) = 7.5 \text{ g } CO_2$$

The combustion of 2.5 g propane will yield 7.5 g carbon dioxide.

An Instructional Learning Progression for Stoichiometry:



Challenge Set I:

- Students' weak pre-knowledge results in struggling with learning new information, particularly information that integrates different concepts, thereby increasing Cognitive Load.
- Students need additional time to assimilate new information.

Solution:

- Decrease Cognitive Load due to gaps in pre-knowledge via instructional videos used as homework/out of class study.

Activity:

- Utilize online instructional videos such as those from Kahn Academy to be used as pre-lecture and support resources for students.

Signs of Success:

- Student performance will no longer reflect gaps in pre-knowledge. Student copes better with pace of class.

Challenge Set II:

- Students will reach their Cognitive Load limit, need an opportunity for recovery and growth.
- Students have poorer motivation when struggling.
- Students are often reluctant to seek assistance from teachers & classmates.

Solution:

- Use productive group work to promote better collaboration skills, increase buy-in, and support with current Cognitive Load.

Activity:

- Stoplight quizzes; performance assessments that track students' individual performances as well as provide an incentive for productive group work providing support in navigating current Cognitive Load.

Signs of Success:

- Students are not so quick to shut down. Decreased students failures & withdrawals from class.

Challenge Set III:

- Leading students to understanding the Mole Concept on conceptual (abstract) as well as mathematical (concrete) levels.

Goal:

- Promote growth of student's Abstract Thought. Increase instructional attention on Abstract Thought, develop Formal Reasoning. Ability with Formal Reasoning eases Cognitive Load with future new material.

Activity:

- Include activities involving estimating & making relative expectations from mass-mole conversions. Don't give up on student growth.

Signs of Success:

- Increased Abstract Thought and ability with Formal Reasoning will reduce future Cognitive Load with regards to problem complexity.

Sources:

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