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How Learning and Cognitive Science Can Improve Student Outcomes

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Students are often fascinated, confused, or sometimes even disturbed by facts that clash with their knowledge or beliefs. Cognitive disequilibrium is experienced and students try to restore clarity (equilibrium). They want to know how and why, and to receive explanations. It is good to challenge students with counterintuitive facts, particularly when they illustrate important material.

THE GEORGE W. BUSH INSTITUTE'S MIDDLE SCHOOL MATTERS INITIATIVE SEEKS TO INCREASE THE NUMBER OF MIDDLE GRADE STUDENTS WHO ARE PREPARED FOR HIGH SCHOOL AND POSTSECONDARY SUCCESS.

Middle School Matters' mission is two-fold: to transform the middle grades by promoting research-based tools, practices, and solutions and to drive the development of policies that lead to better student outcomes. Middle School Matters has two primary elements that will help us achieve these goals: 1) Develop practical tools and supports based on solid research for middle grade reform initiatives, school districts, and middle school campuses so they can drive research into their work and 2) Promote middle grades reform through an alliance with individuals who influence decisions made for/in middle grades.

This paper is written to guide school leaders in reflecting on the current instructional practices in their schools and whether these practices are ones that lead to improved student outcomes. There is research in the fields of learning and cognitive science that can inform instructional decisions to improve learning and retention over time. These instructional practices can be implemented by all teachers in a variety of content areas in a school setting.

There are research-based principles and practices from the learning and cognitive sciences that can be applied to all content areas in middle grades education to improve student outcomes. Even teachers of courses like Physical Education can consider these strategies for assisting students in remembering rules of sports, different sports strategies, etc. More importantly, these principles and practices can provide study skills for students to prepare them for the increased rigor of high school coursework, where they may experience final exams for the first time. Therefore, the more these principles and practices can become adopted and implemented school-wide, the more proficient students will become in their use. This will enable middle grade students to have the skills they need not only for high school success, but also for success in post-secondary education and/or future careers. What follows are a few questions school leaders might ask while providing instructional leadership, observing classrooms, and working with teachers, and how Dr. Graesser would respond based on his knowledge of research in the learning and cognitive sciences.

QUESTION:

What kinds of tasks should teachers in my middle grades school be selecting for students to maximize learning outcomes?

Challenging tasks should be selected that require explanations, reasoning, and problem solving. Students are often fascinated, confused, or sometimes even disturbed with facts that clash with their knowledge or beliefs. Cognitive disequilibrium is experienced and students try to restore clarity (equilibrium). They want to know how and why, and to receive explanations. Therefore, teachers should present challenges to the student that involve obstacles to goals, contradictions, system breakdowns, trade-offs, anomalies, and other types of desirable difficulties. The resulting cognitive disequilibrium will stimulate deep questions, explanations, reasoning, and problem solving. Examples of counterintuitive facts are that whales are mammals rather than fish, that violent crimes are decreasing in the United States, and that sometimes it helps the ecology to set fires in forests. For example, teachers can give students the following types of tasks:

- Identify facts that clash with student beliefs.
- Ask students to defend positions that are different than what they believe (such as is done in formal debates).
- Ask students to explain why the fact exists or occurred.
- Ask students to find counterintuitive facts in different media and to verify that the facts are accurate by accessing reliable sources.

It is good to challenge students with counterintuitive facts, particularly when they illustrate important material.

QUESTION:

How should the teachers in my middle grades school present new information to students?

Design curricula, tasks, and tests in different contexts, media, and practical applications. It is easier for students to generalize and flexibly apply knowledge, skills, and strategies if they learn them across multiple and varied applications. For example, in chemistry, students are often fascinated with the role of catalysts in chemical reactions. Students can explore the dynamics of a particular chemical reaction from multiple viewpoints, such as:

- An animation with the molecules before, during, and after the presence of the catalyst.
- A graph that plots the presence of different chemicals as a function of time.
- A mathematical formula that captures a diffusion process over time.
- A chemist pouring chemicals together and presenting the catalyst.

Therefore, when determining how to present information, there is no one right answer. Information is encoded and remembered better when it is delivered in multiple modes (verbal and pictorial), sensory modalities (auditory and visual), or media (computers and lectures) than when delivered in only a single mode, modality, or medium. Through the use of technology this is no longer a challenge for teachers. Teachers can combine graphics with text, graphics with spoken descriptions, speech sounds with printed words, and use other combinations of modalities to vary how they present materials. Graphic depictions with spoken descriptions are particularly effective for subject matters in science and technology.

There are benefits in connecting and interweaving both abstract and concrete representations of problems in the domains of mathematics, science, and technology. Therefore, once a subject matter is introduced through multiple modes, students should be assigned tasks and problems in different contexts and practical applications. This variability is needed to apply knowledge and skills to new situations.

QUESTION:

What kind of feedback is most helpful for my middle grades school teachers to provide students on their work?

Provide timely qualitative feedback on the student's learning activities. Feedback helps learners modify the way they represent their knowledge (e.g., with words or symbols), their skills, and their strategies to include relevant and useful content. The feedback may identify and correct errors and misconceptions (errors of commission) or help fill in missing information (errors of omission). The optimal timing of the feedback varies for different tasks. Immediate feedback strengthens correct information and prevents elaboration of incorrect information, but has the potential liability of interrupting the learner's organized activities and causing them to acquire skills of self-regulated learning.

Feedback on complex material should qualitatively explain the correct and incorrect information, as opposed to merely flagging that an answer is incorrect or giving the student an overall score. Teachers should explain why answers are correct or incorrect rather than merely giving numerical scores or positive/negative feedback. Qualitative explanations explain why an answer is right or wrong. The characteristics of a good explanation include:

- Identifying the elements in an answer that are problematic or particularly good, (e.g., this statement is false).
- Providing steps in a logical or causal justification for the feedback (e.g., this word is incorrect because ___).
- Contrasting a faulty piece of information with a correct piece of information (e.g., the numbers should decrease rather than increase because ___).

Teachers should give accurate feedback on the student ideas, answers to questions, test items, solutions to problems, writing, performances, and other tasks in a timely fashion. A massive amount of negative feedback runs the risk of losing students with low self-esteem and self-efficacy.

QUESTION:

How can schoolwork improve our students' retention over time of what they are taught?

It is better to distribute the presentation of materials, practice, and tests over time than to block the learning experiences within a short time span. What follows is an example of what might be a common practice in a mathematics classroom (Example 1) and a recommended practice based on the research evidence for improving retention over time (Example 2).

Example 1: Mr. Smith is an 8th grade mathematics teacher who is pressured to finish the mathematics curriculum in one year, prepare students for the state assessment, and cover all of the state standards. He has designed the scope and sequence of the material in his class in units. At the end of each unit students receive a test. He reserves two weeks prior to the state assessment to complete a thorough review of all of the 8th grade mathematics standards so his students are prepared for the test. He is upset to find how much his students do not remember the week they are doing the review. He is concerned about the results of the state assessment and wishes his students would do more at home to study.

Example 2: Mr. Jones is an 8th grade mathematics teacher who attended professional development over the summer to learn about how to improve student learning and retention. He has designed his homework assignments, quizzes, and unit tests to include a spiral review so that students have the opportunity to review new concepts throughout the year. He also has shared a monthly update with other 8th grade content area teachers of the concepts his students are learning in mathematics class, and asks that they find ways to integrate these concepts into their coursework and assignments so that students have additional opportunities to practice and apply the mathematical concepts and skills. The week before the state assessment, he had his students complete a practice state assessment and was pleased with how much they remembered. Mr. Jones is looking forward to the results of the state assessment to confirm that his application of research to his instructional practice has resulted in improved student outcomes.

Delayed re-exposure to the material can be promoted through homework assignments, in-class reviews, quizzes, and other instructional exercises. Tests or challenges to the students can help promote distributed learning experiences and slow down forgetting.

Teachers can present the same or similar material at different times throughout the course. Presenting the same idea in different contexts is particularly helpful so the students can understand it from multiple angles. For example, there are many contexts in which students could learn about the Great Irish Potato famine of 1845–1852:

- Learning about the history of Ireland.
- Learning about fungus infections in crops.
- Learning how a problem in one country can influence other countries.
- Learning how a disease spreads in a population over time, including an exponential formula.

Teachers can also give frequent tests, quizzes, or assignments to force the student to be constantly focusing on the material and distributing their practice to improve learning and retention. Instead of labeling these "tests" all the time, teachers can call them "challenges," to provide a more motivating slant. For example, educational games can be motivating but at the same time test students on facts or difficult concepts. They are not called tests, but a well-designed game can challenge students and expose students to material more frequently.

CONCLUSION

This question-and-answer segment includes a sample of research-based principles and practices in the Learning and Cognitive Science content dimension of Middle School Matters Research Platform that can guide middle grade school leaders and their teachers to organize instruction to promote greater student success. Research from the learning and cognitive sciences along with another 12 areas of research have been compiled in a user-friendly Middle School Matters Field Guide (www.middleschoolinstitute.org) to walk schools through an assessment of what they are currently doing and whether it is aligned with what research has shown to be effective. Schools can then develop an implementation plan to select areas on which to focus improvement. Through the use of ongoing data collection and review, decisions can be made to discontinue practices that are not leading to improved student outcomes and to put more resources and attention into the practices that are resulting in student success.

ABOUT THE AUTHORS

Dr. Art Graesser is a professor in psychology at the Institute of Intelligent Systems at the University of Memphis. He is the current editor of the Journal of Educational Psychology. He has conducted research in the areas of cognitive science, discourse processing, and the learning sciences. His more specific interests include knowledge representation, question asking and answering, tutoring, text comprehension, inference generation, conversation, reading, education, memory, artificial intelligence, and human-computer interaction. As an education researcher for the Bush Institute, Dr. Graesser has participated in Middle School Matters since its inception, providing key research-based principles and practices to guide middle schools in organizing instruction more effectively to improve student outcomes based on knowledge from the learning and cognitive sciences.

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To learn more about these recommendations, we provide a list of a few resources. The complete reference list is available as part of the Middle School Matters Research Platform.

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