PROBLEM SOLVING

In Response to The Deans for Impact Report: How Do Students Solve Problems? Practical Applications for Educators

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The Deans Key Question for Impact report (DFI) presented cognitive and practical applications that support six questions posed by the authors. This article will focus on the key question, "How do students solve problems?" in regards to practical applications. Although the DFI provided strategies and suggestions for application, there were a few areas lacking. The purpose of this paper is to expand on the DFI findings with strategies that can be generalized and utilized across settings. Self-regulation, problem-based learning, and effective feedback are three areas not addressed in the DFI paper. This article focuses on the three areas not addressed by providing practical applications for educators. A variety of strategies that address how students solve problems is presented with samples and examples for educators to reference. Although this paper provides specific strategies that focus on problem solving, the list is not exhaustive and should be used as a foundational tool for educators.

Keywords: Problem-solving, self-regulation, cognitive load theory, feedback, problem-based learning, working memory

The Deans for Impact report (DFI) is a document that contributing authors developed by incorporating a compilation of principles they determined were necessary to impact student achievement and outcomes. This report was based on a review of the literature, and research gathered by the authors was separated into cognitive principles and the practical applications that align with each principle. The DFI report poses six Key Questions and this article addresses the third of these questions, "How do students solve problems?" The Key Question was developed based on various empirical and seminal works, and based on a review of the literature, the DFI (2015) authors presented brief practical applications for educators that illustrate the cognitive principles identified. The purpose of this article is to further develop and support the cognitive principles identified regarding how students solve problems by providing practical applications educators might use within their settings.

COGNITIVE PRINCIPLE 1

Each subject area has some set of facts that, if committed to long-term memory, aids problem-solving by freeing working memory resources and illuminating contexts in which existing knowledge and skills can be applied.

The DFI report (2015) presented the cognitive principle which highlights the necessity of freeing working memory resources in order to improve problem-solving skills within the brain. This section provides research based tools that can be used to improve problem-solving skills by reducing cognitive load. While not mentioned in this Key Question in the DFI report, increasing self-regulated learning skills are critical to helping improve problem-solving skills, and so are addressed in this article. The strategies presented can be adapted to work across levels and content areas. While not an exhaustive list, the strategies presented can help educators begin the process of reducing cognitive load to increase problem solving skills, while teaching students self-regulation skills to improve the effort. It is our hope that these applications will help foster more in-depth thinking by educators regarding different ways to best accomplish this in their classrooms.

Self-regulated learning is a pivotal part of the problem-solving process because the student sets goals prior to the task, then reviews and revises those goals during task completion, and reflects on the learning experience associated with the specific task (Schunk & Ertmer, 2000; Weinstein, Husman, & Dierking, 2000; Zimmerman, 1990). Students who have difficulty or are unable to self-regulate independently are considered novices, while students who self-regulate consistently are considered experts.   Zimmerman (2000) describes self-regulation as an internal process where the student develops thoughts, feelings, and actions (behaviors) to help reach a desired goal.   Self-regulated learning can be a conscious, deliberate action or an automatic response to solve problems (Paris & Paris, 2001). For students who are considered experts, self-regulated learning is a more automatized process for familiar tasks, thus increasing their swiftness and accuracy in response (and reducing cognitive load).   This helps students considered as experts because they are able to solve problems on a deeper and more abstract level than their novice peers. Key aspects to self-regulated learning are described with examples below.

- Goal Setting - Prior to completing a task, students establish learning goals and develop a plan to achieve their goals. This can take on a variety of formats such as use of a student-generated graphic organizer, illustration or drawing, checklist, etc. and is most effective if visuals are used. For example, in lower grades, students use the different panels of a depiction of a hot air balloon to set goals. On each panel or section of the balloon, students write a specific goal they want to achieve in relation to the task, and color in sections of the balloon picture as they attain goals. When the goal is achieved, the balloon is completely colored in.
- Self-Reflection - Once students have completed a task or assignment, they take time to reflect on the learning process. During this time, students self-assess their performance, strengths and areas for improvement. Depending on the level of student, this can be done through conversation with educators and/or peers. The goal of self-reflection is to have students look inward and critically reflect on their learning experience. By self-reflecting students are reinforcing the learning process and are able to better understand how self-

reflection can positively impact problem-solving ability. Teachers should routinely model this for their students in order to help students understand the process in context.

Cognitive load theory explains how cognitive resources are used during learning and problem- solving when a student is assigned a task (Chandler & Sweller, 1991). Researchers Chandler and Sweller indicate that the goal is to reduce cognitive load in order to increase problem solving ability and accuracy (Chandler & Sweller, 1991). Reducing cognitive load increases the ability to solve problems because students are able to determine steps necessary to solve a problem and are consequently given the ability to focus on the problem at hand, rather than all of the additional extraneous information. For educators, determining the level of student understanding about a specific concept or skill is an integral part of the learning process and points to the value of high quality formative assessment practices. Determining the level of understanding will help reduce cognitive overload by eliminating concepts for which students may already have a working knowledge. In a classroom, this can be accomplished by activating prior knowledge. By activating prior knowledge, an educator is informally assessing current understanding of a new concept in order to reduce redundant information presented, thereby reducing cognitive load. These are some examples of how to reduce cognitive load in school:

- K-W-L Charts can be utilized at all levels (elementary, secondary, and post-secondary) and across all areas to help students think about what they know about a concept and about what they want to learn about a new concept. There are many variations on a K-W-L Chart, with K standing for what the student knows about a concept; W for what students want to know or learn about the concept; and L for what the student learned about the concept after instruction. This chart can be posted within the classroom as a reference tool during instruction and used as a review tool. The K section is an embedded instrument for reflection by the learners, and important component to learning oftentimes neglected.
- "In My Head" Thought Bubble is a strategy that gives students the opportunity to brainstorm what they think a word, concept, or skill means. For example, when presenting a new language arts concept to students on figurative language, students may brainstorm what they think the word means or looks like in context. This strategy can be used orally or in written form with a whole group discussion to introduce a new topic.
- Chunking is the strategy for presenting smaller pieces of information, one or a few at a time to decrease working memory overload; This strategy provides more manageable learning opportunities especially for novice learners. In a Language Arts class this might look like the following scenario: As students read a paragraph or section, they bracket or underline the stopping point. Then the student jots down their understanding of the main point or idea of the section on a sticky note. At the end of the chapter, students take all of the sticky notes they have created along the way and merge these into an overall main idea of the chapter.

The DFI report presented the cognitive principle on the necessity of freeing working memory resources in order to improve problem-solving skills. This section provided research based tools that can be used to improve students' problem-solving skills by reducing cognitive load and increasing self-regulated learning skills. These strategies can be adapted to work across levels and content area. Again, while not an exhaustive list, the strategies are presented to help

educators begin the process of reducing cognitive load to increase problem-solving skills, while teaching or strengthening students' self-regulation skills within the lesson.

COGNITIVE PRINCIPLE 2

Effective feedback is often essential to acquiring new knowledge and skills.

Based on the DFI report, for learners to attain goal accomplishment from and through learning, feedback is typically needed and used to direct their efforts toward the described outcomes of the learning activity. Feedback has been studied for decades, and teachers know well the complexity of giving feedback where the result in responses is completely different than the intent with which the feedback was issued. We do know that zeros and "F" grades rarely motivate deeper learning. We also know that some feedback needs to be formative and some summative depending on the goals or scenarios. Recent researchers (Hattie & Timperley, 2007; Shute, 2008) note the critical importance of understanding more precisely what feedback is and how to use it in the classroom to improve teacher and student performance.

Elements of Good Feedback (Shute, 2008).

- Specific and Clear
- Focused on the Task
- Explanatory
- Focused in improving performance

Feedback should not be personal and include statements about intelligence or academic ability, such as "you're smart" or "work harder" (Dean et al., 2012). On the other hand, it should be focused, specific, and fully address how and why a student was marked at a specific level of performance. For example, "Your response demonstrated a superior knowledge of the Battle of Gettysburg and supplied supporting details that illustrated the battle as a turning point in the War of Northern Aggression." The last sentence clearly establishes why and how a student response was deemed exceptional.

Also important is to concept of beginning with the end in mind. Students need to know clearly what the expectations are and how they will be assessed. Below are some ways that educators can develop systems for producing feedback that addresses the elements of good feedback. Some specific examples include criterion referenced rubrics, error analysis/peer review, and role playing.

Criterion Referencing/Rubrics   One way practitioners might create an environment where feedback can naturally develop is through the applications of rubrics and criterion referencing. By using rubrics that establish expectations for certain performance levels, students can know what is expected before they begin an assignment, and can also know how to improve based on their rubric scores. An example rubric is below illustrating elements that could be contained within the rubric.

Writing Rubric

Date: _____

Rater: _____   Course: _____   Student: _____

CRITERIA	Unacceptable	Acceptable	Target	Exemplary	Score
Logic & Organization	Does not develop ideas cogently, uneven and ineffective overall organization, unclear introduction or conclusion	Develops and organizes ideas in paragraphs that are not necessarily connected. Some overall organization, but some ideas seem illogical and/or unrelated, unfocused introduction or conclusions	Develops unified and coherent ideas within paragraphs with generally adequate transitions; clear overall organization relating most ideas together, good introduction and conclusion.	Develops ideas cogently, organizes them logically with paragraphs and connects them with effective transitions. Clear and specific introduction and conclusion.	
Language	Employs words that are unclear, sentence structures inadequate for clarity, errors are seriously distracting	Word forms and sentence structures are adequate to convey basic meaning. Errors cause noticeable distraction	Word forms are correct, sentence structure is effective. Presence of a few errors is not distracting.	Employs words with fluency, develops concise standard English sentences, balances a variety of sentence structures effectively.	
Spelling and Grammar	Writing contains numerous errors in spelling and grammar which interfere with comprehension	Frequent errors in spelling and grammar distract the reader	While there may be minor errors, the writing follows normal conventions of spelling and grammar throughout and has been carefully proofread	The writing is essential error-free in terms of spelling and grammar	
Development of Ideas	Most ideas unsupported, confusion between personal and external evidence, reasoning flawed	Presents ideas in general terms, support for ideas is inconsistent, some distinctions need clarification, reasoning unclear	Supports most ideas with effective examples, references, and details, makes key distinctions	Explores ideas vigorously, supports points fully using a balance of subjective and objective evidence, reasons effectively making useful distinctions	
Purpose	The purpose and focus of the writing are not clear to the reader	The writer's decisions about focus, organization, style, and content sometimes interfere with the purpose of the writing.	The writer has made good decisions about focus, organization, style, and content so as to achieve the purpose of the writing.	The writer's decision about focus, organization, style, and content fully elucidate the purpose and keep the purpose at the center of the piece	

Peer Review/Error Analysis.

● Class A and Class B each write a two-paragraph summary of the battle at Normandy.

● Class A and B teachers review student responses and identify one exemplar and one with opportunities for improvement in two categories (4 samples total) – historical content and significance and grammar and style.

● They trade samples for anonymity and have students from the opposite class read to identify and explain why selected papers were identified in certain ways – strong or needs improvement. This is initially accomplished through small groups and then shared out with the whole group as the teacher highlights areas of strengths and weaknesses from the writings.

● In this scenario, the teachers identify common errors from student work and allow for students to then review the selected samples and offer ideas in the small group that would make the paper stronger or identify weaknesses. The teacher then reviews the samples with the class as they compare and see commonalities between their feedback and the teachers with the purpose of including the strengths of the writing to improve their skills.
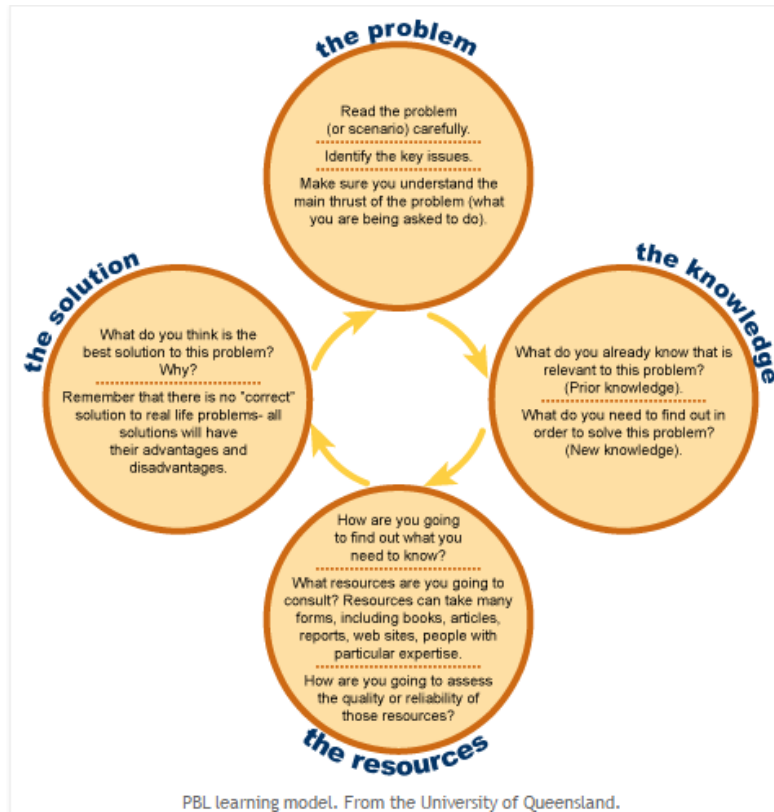
Role Playing.

● Having taught students limits of free speech for students at schools in a prior lesson, students are given a scenario where they must correctly apply student speech protections

and prohibitions as determined in U.S. Supreme Court cases *Tinker v. Des Moines, Bethel v. Fraser, Hazelwood v. Kuhlmeier, & Morse v. Frederick.*

- Three students are assigned to serve as federal judges. Four students are designated to serve a respondent and petitioner (two per side). Three are serving as clerks that are to summarize in brief the issue before the court – from inception to latest ruling (district court).
- Respondents are attempting to overturn a previous ruling using case law or new interpretations; the petitioner is attempting to have rulings upheld.

- The emphasis is on the correct application of the law as supported by court rulings.

- The teacher serves as the moderator and does not comment until both sides have presented and the judges have made their ruling. At the conclusion, the teacher reviews the activity and gives informational-type feedback - feedback on how well they applied the actual law. A need may arise to reteach based on their application of the law to the scenario. The process can then be repeated using a different scenario.

- The teacher may also ask the class to provide feedback as to which side made a stronger argument by distributing performance rubrics for the class to provide greater amounts of feedback.

Problem Based Learning Environments.   Problem Based Learning (PBL) is a classroom strategy which is widely used by educators which incorporates the cognitive principles presented by the DFI report (2015). PBL is an instructional method that is driven by a realistic problem in which students collaborate to develop real world solutions using previous knowledge and skills. PBL environments challenge students to build on previous knowledge to solve real world problems. Throughout the process the instructors give guidance and effective feedback to facilitate learning activities. This method of instruction also conditions students to solve both routine and ill-structured problems and learn from the responses of their peers through the lesson.

PBL environments include three major components that Mayer (1998) discusses are needed for developing effective problem solving skills: domain specific knowledge relevant to the problem-solving task; metaskill – strategies for how to use the knowledge in problem solving; and will – feelings and beliefs about one's interest and ability to solve the problems. Furthermore, PBL environments foster self-regulation which is a large component of the problem solving process (Zimmerman, 2000; Schunk & Ertmer, 2000). The process is illustrated below:

the problem

Read the problem (or scenario) carefully.

Identify the key issues.

Make sure you understand the main thrust of the problem (what you are being asked to do).

the solution

What do you think is the best solution to this problem? Why?

Remember that there is no "correct" solution to real life problems- all solutions will have their advantages and disadvantages.

the knowledge

What do you already know that is relevant to this problem? (Prior knowledge).

What do you need to find out in order to solve this problem? (New knowledge).

How are you going to find out what you need to know?

What resources are you going to consult? Resources can take many forms, including books, articles, reports, web sites, people with particular expertise.

How are you going to assess the quality or reliability of those resources?

the resources

PBL learning model. From the University of Queensland.

Hmelo-Silver (2004) describes the goals of PBL and how it promotes self-directed learning:
In this model students formulate and analyze the problem by identifying the relevant facts from a scenario:

- This fact-identification step helps students represent the problem. As students understand the problem better, they generate hypotheses about possible solutions.

  o An important part of this cycle is identifying knowledge deficiencies relative to the problem. These knowledge deficiencies become what are known as the learning issues that students research during their self-directed learning (SDL).
  o Following SDL, students apply their new knowledge and evaluate their hypotheses in light of what they have learned.

- At the completion of each problem, students reflect on the abstract knowledge gained. The teacher helps students learn the cognitive skills needed for problem-solving and collaboration.
- Practitioners interested in implementing these methods in their classroom should make use of the many resources available to them on how to incorporate PBL in the classroom. An example of a lesson plan explaining biomes is provided below (O'Hora, 2003):

Dude, You Gotta Move

a Problem-Based Learning Project about Biomes

The Problem:

The banner headline of your town's paper seems impossible. Local soil testing has discovered a serious problem. The soil of your community is heavily contaminated with a toxic chemical. The only answer is that everyone must move.

"It's Love Canal or Chernobyl all over again," your mom whispers to your dad. "At Centralia, Pennsylvania the government forced the people to move out of the town," you dad replies.

The government says they will pay to move everyone just once. You must all agree to go to the same new biome. The scientists think that a different biome (from the one you live in now) will be your best chance to survive.

Which biome do you think would be best?

Step 1 - **Each member of the group identifies what they know about biomes.** worksheet doc or pdf

Step 2 - **Identify what you need to learn about biomes.** worksheet - doc or pdf
Be specific. Make a list. here are some examples on other subjects.
Assign the group member who is to find the specific answers/information.

Everyone will be researching information.
Learn how to research elementary | middle school & high school

Step 3 - **1. As a group - Discuss your findings on individual biomes.**
2. Use a decision matrix to sort through your choices. (hint: a spreadsheet makes a handy form)
3. Decide on a new biome and list the reasons for its selection.

Step 4 - **Create a project/report to explain your choice and support its selection.**
Be sure to show the pros and cons of the biomes.
In your presentation, show your choice as compared to **at least 1 other biome.**

Take credit and give credit

Practitioners may utilize PBL environments to strengthen problem solving skills and promote self-directed learning within their students. In PBL teachers serve as a resource to students and assume the role of a guide throughout the problem solving process. This focuses the lessons on learning as opposed to the teaching method (Hmelo-Silver, 2004).

CONCLUDING THOUGHTS

The DFI report (2015) was developed in an attempt to help educator preparation programs better prepare students for teaching in the future. The report provided both cognitive principles and brief application strategies to illustrate the principles presented. The strategies presented in this paper are in addition to the ones in the DFI report because while appropriate, the DFI strategies were too narrow in scope to be generalized across content areas. These strategies are intended to help educators utilize appropriate instructional methods to ensure they are meeting the needs of all student learners. As educators, it is important to understand and incorporate these cognitive principles through examples such as PBL when developing lesson plans in order to maximize appropriate and meaningful learning opportunities. Having a strong understanding of cognitive load theory and how it impacts learning, self-regulated learning, and the importance of effective, meaningful feedback are essential components within a quality instructional plan. While the

strategies provided above are not exhaustive, they do provide a small foundation from which educators can use to increase their toolbox of strategies and methods for instruction.

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