Promoting Reflective Thinking about STEM through CADD Activities

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Abstract

Reflective thinking is very important in order for students to make connections in their learning. The STEM Reflective Guide was designed as a part of a NSF ATE project in North Central Idaho to provide supplemental resources that teachers of CADD in high schools can use to encourage students to reflect on their learning. Through this reflection students can see broader connections between their CADD experiences and STEM concepts, and better transfer concepts in future drafting, design, math, and science problem solving.

Introduction

It is important that reflective activities be included among the various instructional strategies used in technology education to ensure proper learning. Johnson (1997) purported that reflective introspection is necessary for quality learning and transfer to different contextual situations in technology education, even if instruction occurs in rich contexts and involves peer interaction. If engineering and technology education teachers are to be successful in helping students see the connection between their drafting/designing experiences and STEM, then activities that allow students to visit, and revisit, these connections must be present in the instructional process.

Runnel**,** et al. (2013) described several instructional methods that can be used to facilitate reflective thinking in students. These methods included writing a diary or journal, writing a narrative, role playing, explanation, and the use of guiding questions. Interestingly, design diaries or work journals are commonly used by professional engineers. According to Palmer, Holt, and Bray (2008), many engineers regularly encounter new and unique problem situations and recording their process of designing solutions for these problems provides fertile ground for experiential learning and reflection on action. In schools and colleges, the use of a reflective learning journal is a valuable tool for students to develop self-critical reflection, help students apply theoretical knowledge to real applications, and improves performance on multiple-choice quizzes over assigned reading (Burrows, McNeill, Hubele & Bellamy, 2001; Lundström & Booth, 2002; Pavlovich, 2007).

Through reflective introspection, expert problem solvers are able to re-structure ideas, knowledge, and processes stored in their long term memory (Kellogg, 2006). Helping students to see the connection of a drafted or modelled component to science, mathematics, and technology, through various reflective activities, will re-structure students' schema of that component. That restructured schema will influence students' metacognitive process—executive control functions—in the future when they are engaged in solving drafting, design, math, and science problems. The theoretical frame—cycle of self-regulated learning—depicted in Figure 1, illustrates the importance of reflection in self-regulated learning and the development of learners as agents. The reflective process, which is implicit to metacognitive monitoring and control, influences students as they analyze future problem tasks, set goals, devise plans, and enact problem solving tactics and strategies (Woolfolk, 2013). Reflective introspection is therefore important in changing how knowledge is integrated in a student's long term memory and will improve the student's recall and transfer of information (Feltovich, Prietula, & Ericson, 2006).

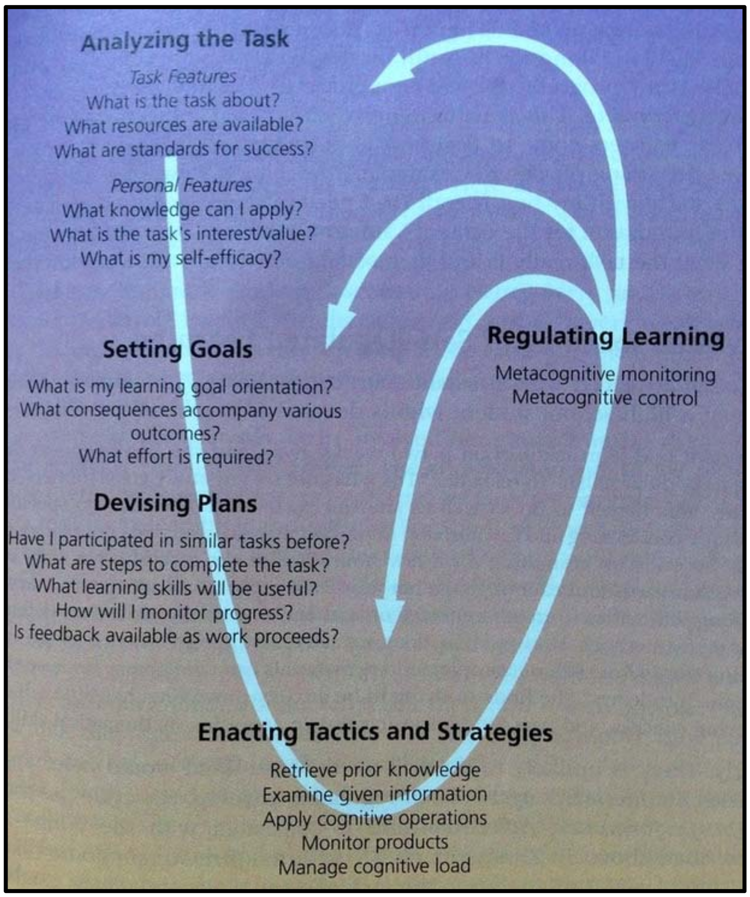


Figure 1. The cycle of self-regulated learning by A. E. Woolfolk, P. H. Winne and N. E Perry (2006)

CADD and STEM

The increased emphasis of engineering design in technology education classrooms can inadvertently present several pedagogical challenges, which may inhibit proper learning and transfer. Some drafting and engineering design problems can induce a high intrinsic cognitive load because of the interaction of the nature of the material and the experience of the learner, who is normally a novice (van Merrienboer & Sweller, 2005). Intrinsic cognitive load is the amount of cognitive processing required to figure the material (Woolfolk, 2013). According to van Merrienboer and Sweller (2005, p.150), "intrinsic cognitive load cannot be altered by instructional interventions because it is determined by the interaction between the nature of the materials being learned and the expertise of the learner." They further added that "Materials with high element interactivity are difficult to understand—and the only way to foster understanding is to develop cognitive schemata that incorporates the interacting elements."

While drafting assignments using solid modelling may not carry the same level of intrinsic load as design, expecting students to grasp the connection between their drafting activity and STEM concepts may inadvertently induce high cognitive load, because of their limited experience. It becomes even more complicated when teaching and reinforcing critical STEM concepts is beyond the efficacy of the engineering and technology education teacher. According to Crismond (2011), technology education teachers often lack the pedagogical content knowledge to cover integrative STEM disciplines efficiently and effectively, and Sanders (2009) indicated technology education teachers tend to emphasize concepts that relate to design rather than STEM. As a consequence, extraneous cognitive load may be imposed because of the use of improper pedagogical strategies. Extraneous cognitive load can be removed by effective instructional interventions, but without proper instructional interventions extraneous cognitive load will persist (van Merriënboer & Sweller, 2005). Expecting students to see and recall connections to STEM during drafting and designing; especially when it is not explicitly highlighted by the technology teacher; might not be possible for many students because of imposed cognitive load. This may result in students' failure to learn, connect, and transfer concepts and processes to other STEM domains.

Aim of the STEM Reflective Guide

Several STEM Reflective Guides were developed as resources for teachers in North Central Idaho. The aim was to provide supplementary instructional resources that technology education teacher can use to encourage students to reflect on their CADD experience. The guides were developed as part of a NSF ATE project and out of a common understanding by educators and manufacturers that resources were needed to aid students to reflect on how their CADD experiences relate to STEM. Through reflection, students can see broader connections between their CAD experience and STEM concepts, increasing their ability to transfer to future drafting, design, math, and science problems.

Components of the STEM Reflective Guide

The guide consists of four sections that address the relationship of science, technology, engineering, and mathematics to a drafted or modelled component. Each section addresses one or two central concepts; e.g. *Friction or Molecular Structure* in the science section and *Extrusion* in the technology section; that relates to the component that was drafted or modelled in class. Each section begins with an overview of the central STEM concept and how it relates to a virtual object the student modelled in their CAD class. Simple concept maps are used to help students connect the central concept to other related concepts or sub-concepts (Figure 2). Students are then guided through a series of reflective activities; through hyperlinks to video clips, online simulations, and informational webpages, visits to laboratory; to help them see the connection of the STEM concept to the modelled or designed component (Figure 3).

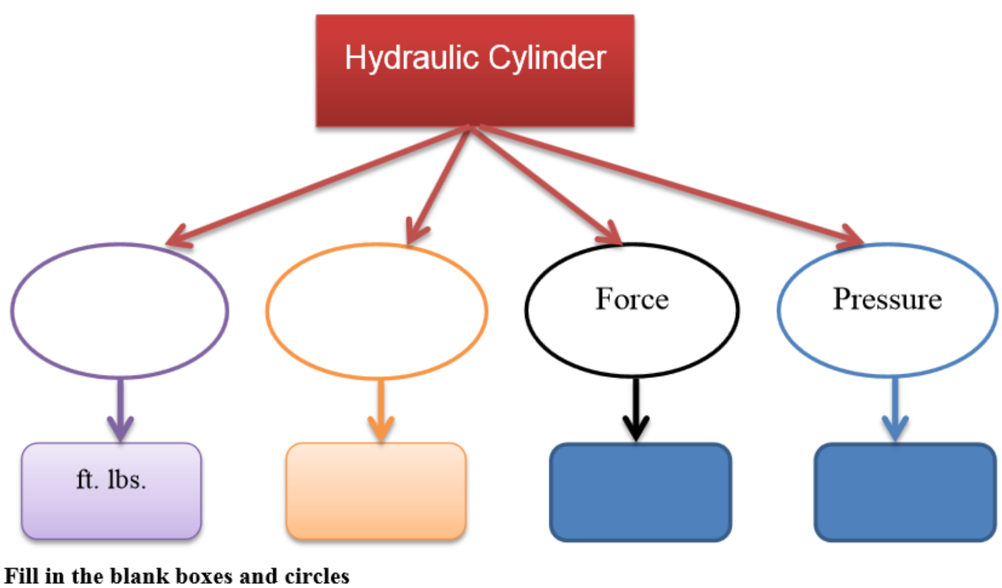


Figure 2. Simple concept map

SCIENCE

Hydraulic Lever

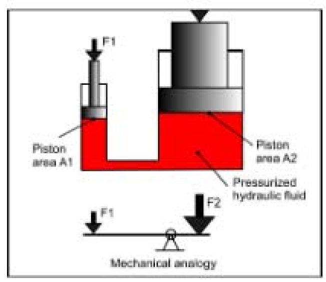
Science Learning Experience # 1 **There are several scientific principles associated with the function of a hydraulic or pneumatic cylinder. However, in this first activity we will focus on the hydraulic lever.**	
Activities	**Special Instructions**
The unique behavior of a fluid, including its ability to transmit an omnidirectional force, was summarized by Blaise Pascal in a theory known as Pascal's principle in 1653. Pascal's principle may generally be stated as follows: *"The pressure applied to a confined fluid is transmitted undiminished in all directions to every portion of the fluid."* This characteristic of a fluid allows it to function as a hydraulic lever. Its function therefore is similar to a mechanical lever. The brake system in a car uses a hydraulic cylinder that follows the same principle of a mechanical lever. Follow the instruction in the column to your right to understand more about the principles behind a hydraulic lever.	**Read** this webpage. It explains how a hydraulic brake system functions as a lever. **Watch** the following YouTube Video: Pascal Law and Hydraulic Brake System. Note in some places the video will pause momentarily. After a few moments it will continue.  Watch this other YouTube about Pascal's Law and Hydraulic Levers.

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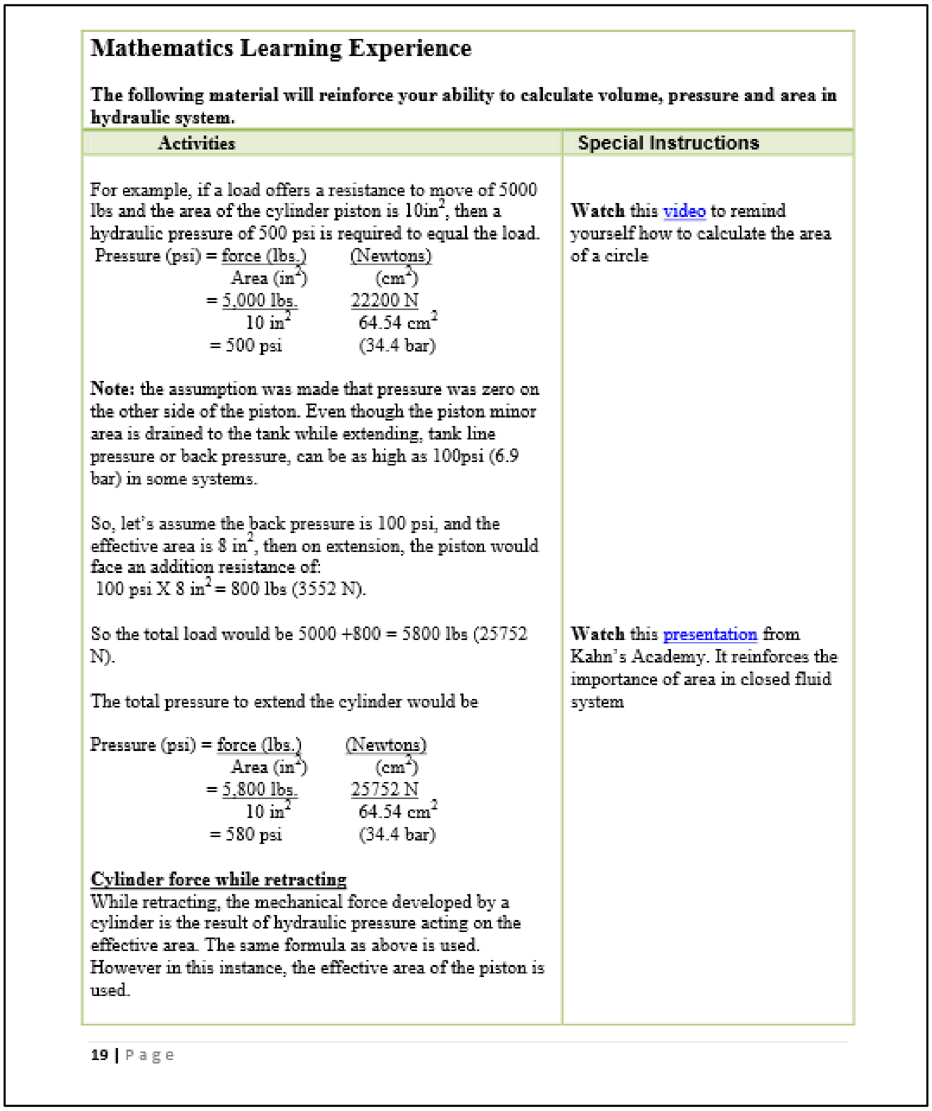
Figure 3. Science section of the STEM Reflective Guide

Additionally, at certain points in the guide, students are encouraged to contact a science, mathematics, or technology teacher to help them better understand a concept. The math and science section typically ends with a problem for the student to solve (Figure 4). The Reflective Guide, therefore, offers students a level of elaborative rehearsal through a series of reflective activities and problem solving. These activities should help students to make connections, remember information, and transfers knowledge in different contexts. The guides are designed to be completed outside of class time, typically in groups of three or four. Students can work together of each sections, then report their learning to the rest of the class.



Mathematics Learning Experience

The following material will reinforce your ability to calculate volume, pressure and area in hydraulic system.

Activities	Special Instructions
For example, if a load offers a resistance to move of 5000 lbs and the area of the cylinder piston is $10in^2$, then a hydraulic pressure of 500 psi is required to equal the load. Pressure (psi) = force (lbs.) / Area (in^2) (Newtons) / (cm^2) = 5,000 lbs. / 10 in^2 22200 N / 64.54 cm^2 = 500 psi (34.4 bar)	**Watch** this video to remind yourself how to calculate the area of a circle
Note: the assumption was made that pressure was zero on the other side of the piston. Even though the piston minor area is drained to the tank while extending, tank line pressure or back pressure, can be as high as 100psi (6.9 bar) in some systems. So, let's assume the back pressure is 100 psi, and the effective area is 8 in^2, then on extension, the piston would face an addition resistance of: 100 psi X 8 in^2 = 800 lbs (3552 N).	
So the total load would be 5000 +800 = 5800 lbs (25752 N). The total pressure to extend the cylinder would be Pressure (psi) = force (lbs.) / Area (in^2) (Newtons) / (cm^2) = 5,800 lbs. / 10 in^2 25752 N / 64.54 cm^2 = 580 psi (34.4 bar) **Cylinder force while retracting** While retracting, the mechanical force developed by a cylinder is the result of hydraulic pressure acting on the effective area. The same formula as above is used. However in this instance, the effective area of the piston is used.	**Watch** this presentation from Kahn's Academy. It reinforces the importance of area in closed fluid system

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Figure 4. Math learning experience

Conclusion

The feedback from teachers that teach CADD has been encouraging with several thinking that this resource is very useful in helping students to see the connection between what they do in their CADD classes and what they learn in their science and math classes. Effort was made to leverage available online resources and those resources available on school campuses to improve student's engagement in each section. Research, however, need to be done to explore students perception of the guides and whether, when used as a supplemental instructional intervention, it improves students ability to make connection to STEM concepts and improve their transfer.

Acknowledgement

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