A new context isn't a new problem: strategies to help students transfer skills

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As a physics teacher, I have always been very interested in students' abilities to apply previously learned mathematical skills in the classroom. This interest stems from my observations of common mistakes students make on what might be viewed as "type" questions (such as the equations for projectiles, or resistors in parallel). In an effort to understand why students some mistakes are more common than others, I have collaborated with colleagues over the years to try to understand students' abilities to manipulate the mathematical equations found in science. To this end, we designed a multiple-choice diagnostic, in which students were given a list of equations found in the science curricula and asked which rearrangements were correct (example provided below). If students were unable to rearrange an equation, we asked them not to guess.

3) When two resistors are connected in parallel, the total resistance of the circuit, R_T, is given by:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$$

Which of the following rearrangements is correct to solve for the total resistance?

A) $R_T = \frac{1}{R_1} + \frac{1}{R_2}$ B) $R_T = R_1 + R_2$ C) $R_T = \frac{R_1 + R_2}{R_1 R_2}$ D) $R_T = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$ E) Unknown

When we analyzed the results of grade 12 students, we found that there are some equations students found more challenging than others. Overall, males and females showed the same trend in performance on each question. Kinematics equations (with no exponents), concentrations, biological ratios, energy, and molarity were among the most successful equations rearranged by students. However, equations using logarithmic scales (e.g. pH), or inverse relationships (e.g. resistors in parallel), were among those which students seemed to find the most challenging (Richardson & Grant, 2015).

What was curious was that we found no significant correlation between the number of grade 12 math courses a student had successfully completed and their ability to manipulate the equations (Richardson & Grant, 2015). This result surprised us. If there is no significant difference between students' success at rearranging equations and whether they have completed one or three math courses, what is going on? One reason might be *transference*.

Strategies to help students with "skill transfer"

Transference, or the transfer of learning, is the application of learned knowledge in a new context and can sometimes be a big challenge for students. As experts, teachers chunk problems in specific ways because we have developed mental structures and strategies to process information and approach problems (Lazanas, 2006). However, because students are novices in their subject areas, their *schema* is not as well developed. The result is that when students face a problem in a different course, they may view it as entirely new and revert to solving it very inefficiently even when they have procedural knowledge that could help them with a task (Kolfschoten, Lukosch, Verbraeck, Valenin & de Vreede, 2010). The good news, is that there are strategies teachers can use to support students as they develop their ability to transfer mathematical skills.

Students need to both be exposed to the same skills in different areas (LaVerdiere, 2008) in order to deepen their understanding, and learn procedural and metacognitive strategies to support understanding of how they are solving problems (Olivares, 2010). Calais (2008) found when teachers devote class time focusing on fewer mathematical problems and guide students to develop their self-explanations that simultaneously strengthen and weaken approaches appropriately, students become more likely to understand how to solve new problems in new contexts than if they do more problems with less emphasis on strategy building. As students improve their ability to self-explain their own approaches, they can benefit by explaining solutions – correct and incorrect – that have been completed by others in order to develop this skill. Active-learning and formative assessments, such as pre-class assignments, think-pair-share, instant personal response gathering (think in-class polling), and written activities, are also found to be effective strategies to teach math skill transfer (Hester, Buxner, Elfring & Nagy, 2014). In my own classroom, I find it is also helpful to have students work through their solutions and explicitly identify when they have used those techniques before in other classes (whether from math, computer programming, or other science classes). This works not only for the student providing the explanation, but also for those students developing their own transference skills.

While some concerns have been voiced about sacrificing class time to support students in developing their ability to transfer skills, Hester et al. (2014) found that taking time to focus on math skills, such as algebra, unit analysis, probability, and graphical analysis in a subject-relevant context more than made up for "lost" time. Students on post- assessments did equally well on content questions, and better on questions with quantitative content, as compared to those classes that did not focus on supporting students in their mathematical skill development (Hester et al., 2014).

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