Learning and teaching practices continue to evolve through action research by educational innovators who test and share their best practices.

High quality learning and teaching practices are advanced through the sharing of research-based best practices. While "research" may sometimes imply expensive high-level studies that assiduously follow strict scientific principles, as often as not, research-based **best practices** tend to come as a result of action research, where a single individual or a small group of practitioners "analyze data available to them in order to improve their own practice" (Rigsby, 2005). While many other practices are presented elsewhere in this article, a few examples of research-based best practices in Process Education are presented in this section.

- Cooperative Learning (see also the **Learning Communities** section)
- Active Learning (see also **Learning to Learn**)
- Relevance of Learning Activities
- Elevating Learning to Problem Solving (see also **Problem Solving**)
- Validation of Learning
- Triggering of Prior Knowledge (see also the **Learning Process Methodology**)
- Concept Maps as a Learning Tool and Activity

Cooperative Learning
(also see the **Learning Communities** section)

The jury has long been in: cooperative learning works. According to Prince in *Does Active Learning Work? A Review of the Research* (2004),

> …there is broad empirical support for the central premise of cooperative learning, that cooperation is more effective than competition for promoting a range of positive learning outcomes. These results include enhanced academic achievement and a number of attitudinal outcomes. In addition, cooperative learning provides a natural environment in which to enhance interpersonal skills and there are rational arguments and evidence to show the effectiveness of cooperation in this regard.

Though the professionals at Pacific Crest did not invent cooperative learning, they were quick to adapt and apply the practice when they noticed its efficacy. Dan Apple recalls,

> In 1985 when we were running POINT FIVE workshops, there were often a limited number of computers, so the workshop facilitators often paired two faculty members on a single computer. We observed that faculty moved more quickly and effectively through the workshop content when they worked in pairs than when they worked alone because in pairs, they taught each other. In student demonstrations, the results were much more positive when students worked in teams of three or four than in pairs. (See the **Learning Communities** section.)

Pacific Crest published a paper on cooperative learning (Duncan-Hewitt, Mount & Apple, 1994) and shortly thereafter published, the *Handbook on Cooperative Learning* (Duncan-Hewitt, Mount & Apple, 1996). Sinclair Community College contributed the design of Team Role Markers (1998) which are now used in Professional Development Institutes and Learning to Learn Camps.

The scholarship on cooperative learning was extended with the publication of modules in the *Faculty Guidebook*: *Cooperative Learning* (Van Der Karr & Burke, 2007), *Designing Teams and Assigning Roles* (Smith, 2007a), and *Team Reflection* (Hare, 2007).

Beyond the *Faculty Guidebook*, the Transformation of Education (Hintze, Beyerlein, Apple, & Holmes, 2011) aspect, "social orientation" contrasts the "individual" orientation with the "community" orientation, offering tips for moving toward more cooperative practice:

- Have students assess one another's individual work. The boost of having another student identify strengths and assist in improvement makes collaboration more attractive.
- The use of formal team roles can help bridge the gap between individual efforts and team results.
- Allowing teams to compete shifts competition/ identity from an individual to the group. Shared win = celebration; shared loss = commiseration.

As noted in the **Learning Communities** section, cooperative learning is integrated into both *Foundations of Learning* (4th ed.) (Redfield & Hurley-Lawrence, 2009) and *Learning to Learn: Becoming a Self-Grower* (Apple, Morgan & Hintze, 2013). Additionally, team roles are used in *Foundations of Biochemistry* (4th ed.) (Loertscher, Minderhout, & Frato, 2015). The introduction to the instructor explains, "These materials were written using a process-oriented guided-inquiry learning (POGIL) model and are expected to be used in structured small groups with instructor facilitation." A typical first step of a learning activity plan is for a team manager to assign the roles of spokesperson, recorder, and reflector.

The *Student Success Toolbox* (Pacific Crest, 2011) offers numerous tools to support the use of cooperative learning practices in any classroom:

Rubrics: Performing in a Team

Forms: Team Assessment Report (with a completed sample), Planner Report, Recorder Report, Weekly Recorder Report, Reflector Report, Weekly Reflector Report, Spokesperson Report

Methodologies: Teamwork Methodology

Other: Team Roles (including performance criteria for: Captain, Recorder, Spokesperson, Reflector, Technology Specialist, Optimist, Planner, Timekeeper, Critical Thinking, Conflict Resolver, Spy), Profile of a Strong Team Player

Active Learning
(see also **Learning to Learn**)

"All genuine learning is active, not passive.
It is a process of discovery in which
the student is the main agent, not the teacher."
M. J. Adler (1982)

The key ideas shared at the first Teaching Institute in 1991 focused on teaching students how to learn (Apple, 1991); this is the definition of *active learning*, according to Bonwell & Eison (1991): the responsibility of learning lies with the learner.

The best practice, in this case, is described by the Transformation of Education (Hintze, Beyerlein, Apple & Holmes, 2011) aspect, "delivery," which defines *active learning* as the opposite of "presentation." In usual terms, this takes place in a lecture-style context, in which there is a teacher who dispenses learning, knowledge, information, or wisdom to a student. Because of this traditionally defined context, we are used to thinking of "learning" as the receiving end of "teaching." But in an **active learning** environment, the learner drives the learning process.

If the learner is responsible for learning and actively engages in doing so, then instead of "teaching," the educator must shift to a role of supporting the learner and facilitating the process of learning. In the role of facilitator, the focus is on process rather than content (see the **Facilitation** section). Several modules in the *Faculty Guidebook* speak directly to this changed role: *Facilitation Overview* (Smith, 2007b), *Facilitation Methodology* (Smith & Apple, 2007), *Constructive Intervention* (Leise & Smith, 2007), *Constructive Intervention Techniques* (Smith & Leise, 2007), and *Profile of a Quality Facilitator* (Smith, 2007c). Beyond the *Faculty Guidebook*, pertinent scholarship in Process Education includes *Transforming Large Introductory Classes into Active Learning Environments* (Duffrin, Dawes, Hanson, Miyazaki, & Wolfskill, 1998-1999).

A well-known and very popular active learning approach is POGIL (Process-Oriented Guided-Inquiry Learning). In POGIL classrooms or activities, though the responsibility for learning still resides with the learner, the active learning is group-based, with learning teams working to discover and construct knowledge (Hanson & Moog, 2007). Whether active learning is performed by an individual or group, the key is that the learner actively seeks out understanding, engaging in some kind of learning process or cycle. In a POGIL activity, the learning process consists of three stages: exploration, concept invention/formation, and application (Abraham, 2005). These three stages correspond to Steps 9, 10, and 11 in the Learning Process Methodology (see the **Learning Process Methodology** section):

9 Models

Study and review examples that assist in meeting the learning objectives and performance criteria

10 Thinking Critically

Pose and answer questions that stimulate thought and promote understanding

11 Transfer/Application

Transfer knowledge to different contexts; apply knowledge in new situations

Because Process Education **is** active learning, all Process Education curricula are, by definition and design, active learning curricula, created to support active learning classroom practices. The only difference is with respect to non-disciplinary curricula, such as *Foundations of Learning* (Redfield & Hurley Lawrence, 2009) and *Learning to Learn: Becoming a Self-Grower* (Apple, Morgan & Hintze 2013). Not only are these books designed to support active learning; the issue of shifting responsibility to the learner is explicitly addressed. The following is excerpted from the introduction to *Foundations of Learning*:

> With this book, you become the master of your learning experience and the person in charge of your own learning. It might help to think of yourself as an "athlete of learning." As a student, you are in training to strengthen and hone your ability to learn... You're not on your

> own; you have professors and instructors who act as coaches to facilitate your growth and improvement. But the bottom line is that just as no one else can exercise for a runner, no one else can do your training for you.

Relevance of Learning Activities

One of the lessons of active learning is that meaningful learning requires active engagement on the part of a learner. If a learner is curious about and interested in a topic, he or she is motivated to learn and is that much more active and engaged. Learning becomes enjoyable and meaningful. Who among us does not recall approaching a learning situation with skepticism, feeling that this is what others want us to learn, for their own reasons, with little regard for our interests or other demands on our time? "Why should I bother?" or "What's in it for me?" are fair, if not terribly polite questions. The key is relevance. If a topic is relevant to a learner, it matters. As educators, we know that what we teach does matter, but knowing this is not enough if we want active and engaged learners. We have to show them that relevance. We have to show why they should bother and what's in it for them.

Why?

The first step of the Learning Process Methodology is to consider the question of why the learning is relevant; a learner should begin by identifying and explaining their reasons for learning. The Learning Process Methodology informs the Activity Design Methodology (because a learning activity is useless unless it supports the learning process), and Step 4 of that methodology is, "Create the 'Why' for the activity" (Leise, Beyerlein, & Apple, 2007). As explained in the *Activity Design Handbook* (Pacific Crest, 2008),

> This section should put the activity in context for the learner by addressing three questions:
>
> - What will the student learn? (clarifies the title and further defines the content of the activity)
> - Why is it relevant to the subject? (defines the general importance of the activity and describes how it fits into the course)
> - Why is it relevant to the learner? (provides justification for the activity from the perspective of the individual learner)

While all Process Education learning activities contain a "Why?" statement, an interesting variation on this practice is found in *Foundations of Organic Chemistry* (Bucholtz, 2015), where, instead of a prompt of "Why?", that section is titled, "Who Gives a Darn?" Ehren Bucholtz, the book's author, explains:

> Students often see the material of a typical day to be esoteric, and don't really understand why this material is useful to learn. Therefore, the start of each activity in the workbook presents a new problem; presented as a **"Who Gives a Darn?"** question. Students then work through an activity that is based on POGIL principles that addresses the learning objectives of the day. At the end of the activity, the "Who Gives a Darn?" question is presented once again, and students are guided through the thinking to solve the problem using the knowledge and skills gained in the activity.

See Figures 1 and 2 for an example.

Real-World Problems and Problem-Based Learning

In addition to a compelling "Why?" statement, the use of real-world problems and problem-based learning (instructional methodology that challenges students to seek solutions to real-world problems; Duncan-Hewitt, 2007) are other strategies to make learning more relevant. Reviewing Figures 1 and 2, we see that they comprise an excellent example of using a real-world problem. Not only is global warming seemingly omnipresent in the media, it is as much a real-world a problem as it is possible to have in that the potential impacts will be noticed by and will affect everyone. *Solving Real Problems in Chemistry* (Goodwin, Slusher, Gilbert & Hanson, 2009) is another example of curriculum that is designed to use real-world problems to increase student performance in solving problems. Various activities challenge students to

- Determine whether a homeopathic medicine is a placebo
- Calculate the fuel value, cost, economic value, and environmental value of various fuels (wood, coal, liquid propane gas)
- Determine the time of death for a corpse found at the side of the road
- Calculate where to build an aluminum plant based on the average residential price for energy
- Predict the useful lifetime for instrumentation used on Mars

While neither *Foundations of Organic Chemistry* nor *Solving Real Problem with Chemistry* use Problem-Based Learning in its strictest definition (i.e., students are not asked to develop a problem statement nor must they determine the information and resources they will need to solve the problem), they do share with PBL that, "appropriately designed, the problems engage students' curiosity so that they are motivated to explore the subject beyond simple solutions" (Duncan-Hewitt, 2007).

Figure 1 *Foundations of Organic Chemistry* Activity 36 Who Gives a Darn? Introduction

Who Gives a Darn?

The global climate has changed dramatically in the last 100 years, coinciding with the industrial revolution. During the industrial revolution, coal fired plants brought civilization generation of electricity. Coal is still one of the most common sources for generating electricity. Unfortunately, the billions of tons of coal burned every year, also contributes to the dramatic increase of carbon dioxide found in the atmosphere. Prior to the industrial revolution, the amount of CO_2 in the atmosphere was generally 200 to 250 parts per million, but now that amount is closer to 400 parts per million. During this time frame the average temperature of the Earth has increased about 1°C.

The balance between heating and cooling the planet is shared between two major types of light energy. As the sun shines on the earth, ultraviolet light penetrates the atmosphere warming the planet. This light energy is released back into space via infrared radiation from the earth.

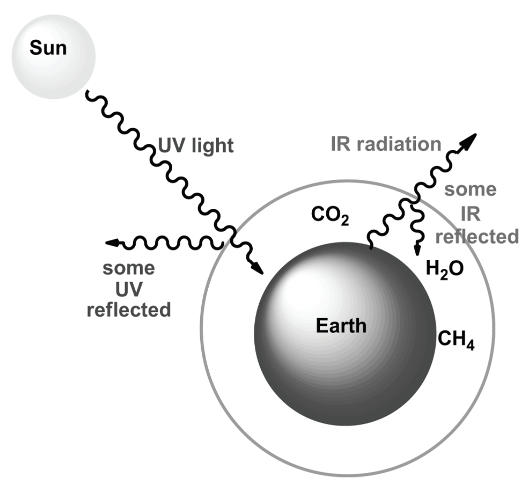
The Earth's temperature is predicted to continue to increase if the amount of carbon dioxide in the atmosphere continues to rise. While 1°C change may not seem like much, it has already resulted in much more violent weather patterns as well as increases in sea level. What is it about carbon dioxide in the atmosphere that disrupts the cooling of the Earth?

Figure 2 *Foundations of Organic Chemistry* Activity 36 Who Gives a Darn? Conclusion

Who Gives a Darn? I Do!

The balance between heating and cooling the planet is shared between two major types of light energy. As the sun shines on the earth, ultraviolet light penetrates the atmosphere warming the planet. This light energy is released back into space via infrared radiation from the earth. Molecules in the atmosphere act as insulation trapping some of the infrared radiation, and help to maintain the Earth's temperature. This has been simplified by calling it the greenhouse effect.

The Earth's temperature is predicted to continue to increase if the amount of carbon dioxide, water vapor and methane in the atmosphere continues to rise. Using what you have learned today about IR spectroscopy, explain this phenomenon.



In both *Foundations of Learning* (Redfield & Hurley-Lawrence, 2009) and *Learning to Learn: Becoming a Self-Grower* (Apple, Morgan & Hintze 2013), students are challenged to solve their own problems, issues, and challenges. While the problems elected by an individual student to work toward solving may not be universal, for that student, no other problem is more real or potentially more motivating.

Elevating Learning to Problem Solving (see also **Problem Solving**)

The best practice here is seen in the Transformation of Education (Hintze, Beyerlein, Apple, & Holmes, 2011) aspect, "cognitive complexity," the degree to which training and doing is elevated to problem solving and research. For this aspect, "memorizing" represents the historical tendency, while "problem solving" is the preferred alternative.

As Smith explains in *Setting High Expectations* (2007d),

> When facilitators set high expectations they are communicating that they think that students are capable of significantly improved performance. In other words, if their teachers believe in them, students are more likely to believe in themselves.

The implication for learning activities is that they should sufficiently challenge students. Integrating critical thinking questions into activities helps students shift from memorizing to understanding and constructing meaning (Hanson, 2007), especially when those questions are sequenced to guide inquiry through multiple levels

Figure 3 The First Three Levels of Learner Knowledge and Critical Thinking Questions

Level I Information	***Directed Questions*** *The answers can be found by examining the model presented in the activity, using the information resources listed, or by drawing on personal experience and prior knowledge and activities. Such questions have a definite answer and build the foundation for more challenging questions.* What is…? Where is…? When did…? What facts or ideas show…? Who were the main…? Which one…? Can you recall…? Can you select…? Can you list the three …? Who was…?
Level II Conceptual Understanding	***Convergent Questions*** *Build Level 2 knowledge and help students elevate their knowledge to Level 3. Students need to organize, interpret, analyze, and synthesize. They may have more than one correct answer, and the level of difficulty progresses within a sequence of questions. A good convergent question makes important connections, links concepts together, leads to better understanding, and requires that students reach conclusions.* How did… happen? How would you compare or contrast…? How would you describe…? How would you summarize…? How would you show an understanding of…? How would you state or interpret in your own words…? What is the main idea of…? Which statements support…? Can you explain what is happening…? What is meant by…?
Level III Application	***Divergent Questions*** *Divergent questions send students in new and interesting directions. They often have no right or wrong answer, but require students to ponder, explore, generalize, and expand their current knowledge. Divergent questions require the highest level of thinking and produce outcomes and conclusions that vary among learning teams and individuals. They help identify holes in knowledge and test understanding by challenging the knowledge structure that was built.* How would you use…? What examples can you find to…? What would result if…? Can you make use of the knowledge to…? What approach would you use to…? What other way would you plan to…? How would you apply what you learned to develop…? How would you structure an argument to show…? What elements would you choose to change…? What questions would you ask in an interview with…?

of learner knowledge (Hanson, 2007). Figure 3 pulls together the pertinent Levels of Learner Knowledge with information about how each level corresponds to the sequencing of critical thinking questions.

The **Problem Solving** section discusses the use of problems in curricula to elevate learning to the level of problem solving. From the perspective of scholarship, this elevation was the focus of the Problem Solving Across the Curriculum Conferences (Kramer & Beery, 1990), as well as *Learning Through Problem Solving* (Apple, Beyerlein & Schlesinger, 1992), *Foundations of Problem Solving* (Myrvaagnes, 1997), and *Developing Working Expertise (Level Four Knowledge)* (Nygren, 2007).

Validation of Learning

A key facet of learning to learn is that learners must develop the ability to validate their own learning; they must be able to **know** that they have learned. This idea is explored in the *Faculty Guidebook* module *Self-Validation of One's Learning* (Armstrong, 2007) and implemented practically in *Foundations of Mathematics* with a section called "Identify and Correct the Errors" (Fremeau 2005). As the sample problem from this section in Chapter 3 makes clear, this innovation asked students not only to demonstrate that they had learned by showing the "correct process" but to validate that learning (see Figure 4).

Validation is included as a critical aspect of learning to learn in other active learning curricula published by Pacific Crest (see Figure 5):

Additionally, students at any of the quantitative Learning to Learn Camps (e.g., Algebra Learning to Learn Camp), are required to validate each answer as part of the process of showing their work in order to receive credit for having the correct answer.

Figure 4

Worked Solution *What is Wrong Here?*	Identify Errors or Validate	Correct Process	Validation
1) $6-4\frac{1}{3}$ 6 $-4\frac{1}{3}$ $2\frac{1}{3}$	Just brought down the 1/3. Did not borrow from the whole number 6 to subtract the 1/3.	$6 = 5\frac{3}{3}$ $-4\frac{1}{3} = -4\frac{1}{3}$ $1\frac{2}{3}$ Answer: $1\frac{2}{3}$	$1\frac{2}{3}$ $+4\frac{1}{3}$ $5\frac{3}{3} = 5+1$ $= 6$ ✓

Figure 5

Book	Validation Innovation
Foundations of Mathematics (Fremeau, 2005) *Foundations of Algebra* (Ellis, Teeguarden, Apple, & Hintze, 2013)	Identify and Correct the Error (see figure 4)
Solving Real Problem in Chemistry (Goodwin, Slusher, Gilbert, & Hanson, 2009; Goodwin, Hanson, & Wolfskill, 2012)	A "Got It" section gives students an opportunity to validate the learning they have done during the activity by solving an additional problem
Foundations of Learning (4th ed.) (Redfield & Hurley Lawrence, 2009)	The Learning Process Methodology includes Step 13: "Validation of Learning"
Quantitative Reasoning and Problem Solving (Ellis, Apple, Watts, Hintze, Teeguarden, Cappetta, & Burke, 2014)	A "Troubleshooting" section gives students an opportunity similar to that found in Identify and Correct the Error, except that there is only one problem offered and it is much more extensive, requiring that students potentially validate multiple aspects of the problem. A "Hardest Problem" section challenges students to create the hardest problem they can, using what they have learned in that activity. This helps them to validate that they have learned by successfully transferring their learning to a new context.

Clear Expectations: Defining and Describing the Target (see also **Performance Criteria**)

"The first step is, of course, seeing that goal or target.
After all, the better you can see a target,
the greater your chances of hitting it."

–*Foundations of Learning* (4th ed.)
(Redfield & Hurley Lawrence, 2009)

While much about performance criteria is covered in the **Performance Criteria** section, a best practice is to keep in mind that, in the terms of the quote above, we have to see the target in order to have a hope of hitting it. This is why Step 5 of the Learning Process Methodology is "Performance Criteria: Determine specific desired outcomes used to measure and gauge performance" (Leise, Beyerlein & Apple, 2007). If we don't know what the outcome or end is supposed to look like, how can we determine whether our learning performance is finished, let alone whether we have learned?

Simply telling students that we expect high-quality performance from them isn't nearly enough; they need to know what constitutes such a performance – what that looks like. For this reason, exemplars and models are invaluable. Additionally, having an exemplar to refer to makes it much easier to write performance criteria; after all, those criteria simply describe the kind of and level of performance we're seeking. This holds true across academic levels, from the program level, to the level of a course, and finally down to the level of individuals and teams (see Figure 6). In each instance, where the methodology recommends brainstorming, being able to look to a clear example of the level of performance being sought not only helps the individual writing the criteria, but it gives a performer an example of the ideal performance to use as a model or exemplar.

Figure 6 The Step for Identifying the Target Performance from the Appropriate Methodology for Writing Performance Criteria (for a Program, for a Course, for Individuals/Teams)

Program Level
Brainstorm a list of your program's future qualities; characteristics and descriptors that reflect what the program will be about, especially those that represent quality (Nibert, 2007).
Course Level
Brainstorm qualities that describe top performing students (Hinton, 2007).
Individuals/Teams Level
Describe the performance expected by all stakeholders, including the performer(s). Brainstorm to get a list of areas of quality that can be observed within the expected performance (Utschig, 2007).

Providing clear expectations through performance criteria at the activity, course, and program levels allows for the synergy of faculty and students to align their efforts to meet the designed expectations (Hinton, 2007).

This practice of providing clear expectations through performance criteria and modeling is seen in *Foundations of Learning* (Redfield & Hurley-Lawrence, 2009). In the first chapter, the Performance Levels for Self-Growers is presented as a rubric. Five sample students are described immediately afterward, with each student talking about their performance at that level (see Figure 7).

Triggering of Prior Knowledge (see also the **Learning Process Methodology**)

While Step 3 of the Learning Process Methodology says that a learner must "identify necessary skills and background knowledge needed to perform the learning," (Leise, Beyerlein & Apple, 2007), as noted in the Learning Process Methodology section, brain-based research recommends that prior knowledge be activated when a learning activity is started in order to increase comprehension (see especially Maguire, Firth, and Morris, 1999).

Quantitative Reasoning and Problem Solving does this with an activity section called "What Do You Already Know?" which triggers students to explore both the potential richness and boundaries of their prior knowledge (Ellis, Apple, Watts, Hintze, Teeguarden, Cappetta & Burke, 2014). *Learning to Learn: Becoming a Self-Grower* (Apple, Morgan & Hintze, 2013) is also designed to trigger prior knowledge through the use of a discovery exercise and exploration questions. The discovery exercise is more immersive and experiential while the exploration questions prompt the learner to begin thinking more analytically about their experience and current understanding. Figure 8 shows the discovery exercise and exploration questions for Experience 13: Choosing and Using Mentors Effectively.

Figure 7 Performance Descriptions in a Rubric and Student Models/Examples for Each Level

RUBRIC

Table 1.2 Continuum of Performance Levels

	Knowledge	Social Interactions	Attitude	Abilities
Level 5 *Star Performers*	Can construct and modify models; valued and respected by experts in the field	Create movements and organizations that often become self-perpetuating	Control their destiny; also can control their emotions in challenging situations	Have highly developed learning and research abilities that enable them to excel
Level 4 *Self-Starters*	Are able to add to the knowledge in their discipline	Use relationships effectively to attain success for themselves and others	Seek greater challenges and responsibilities to perform at a higher level; push the boundaries of their own performance	Able to cultivate new abilities in unfamiliar areas
Level 3 *Responsive Individuals*	Use their problem-solving, learning, and thinking skills to improve their performance and get higher-quality results	Are positive people whom others enjoy and want to have on their teams	React to challenges with improved performance rather than complaints, feeling good about their accomplishments	Are able to learn from how other people function in a particular area
Level 2 *Content Individuals*	Are satisfied with their modest levels of effort in gaining knowledge	Interact freely with family and friends, but do not seek more diverse contacts and more challenging relationships	Feel like a cog in the machinery, doing little more than what is asked, feeling their contributions are not very significant	Have enough critical thinking and analytic abilities to perform some problem-solving
Level 1 *Static Individuals*	Try to minimize or avoid the effort needed to gain knowledge	Limit their social interactions to like-minded individuals who complain about what they are not getting out of life	Feel that whatever they do will have little impact, that most things are not worth the effort	Must have explicitly defined rules, procedures and policies; need to be prompted to finish something

Note that the exploration questions are **not** critical thinking questions. They are preparatory to reading or working with a model and are intended purely to trigger prior knowledge and help students become more metacognitively aware as they begin the reading assignment contained in the pre-activity. Exploration questions are now being used in the Online Teaching Institute to help faculty learners in the same way.

As a final example, *Foundations of Organic Chemistry* (Bucholtz, 2015) shows an instructor making the shift from listing knowledge prerequisites to triggering prior knowledge. The book's author, Ehren Bucholtz, realized that his students didn't know what to do with a listing of prerequisite knowledge as shown in Figure 9; they simply ignored it, as it wasn't a task—it wasn't performance based. The listing of information wasn't triggering their prior knowledge. When Bucholtz upgraded the book from the pre-market to the 1st edition (pending publication), he rewrote the prerequisite knowledge section as performance tasks, also letting students know where to go to review content in those cases when they did they not have the prior knowledge required to complete the task. Figure 10 shows the new version of the prerequisite knowledge for this same activity.

Concept Maps as a Learning Tool and Activity

Concept maps (see Figure 11 for a simple example) are a useful learning tool and, for promoting knowledge retention and transfer, an effective (and possibly preferred) learning activity is to create concept maps. According to Nesbit and Adesope, authors of a large-scale meta-analysis of concept map studies,

> The meta-analysis found that, in comparison with activities such as reading text passages, attending lectures, and participating in class discussions, concept mapping activities are more effective for attaining knowledge retention and transfer. Concept mapping was found to benefit learners across a broad range of educational levels, subject areas, and settings. (2006)

Concept mapping is listed as an appropriate in-class type of learning activity in *Overview of Learning Activities* (Wasserman, Davis & Astrab, 2007) and has been increasingly featured as part of activities or experiences in curricula from Pacific Crest.

In *Learning to Learn: Becoming a Self-Grower* (Apple, Morgan & Hintze, 2013), Experience 11: Metacognition: Thinking About My Thinking, students are given two mod-

Figure 8

DISCOVERY EXERCISE	Think about your personal history and identify the three individuals in your life, other than parents or guardians, who have most helped you to become the person that you want to be. For each of these individuals, determine the three areas where they helped you to grow or develop and how they did that (through what types of action or activity). Also determine the characteristics the individual had that enabled them to help facilitate your growth.

EXPORATION QUESTIONS	1. What are the key roles of a mentor? 2. What are critical characteristics of quality mentors? 3. Why would someone mentor someone else? 4. How do you get someone that you know to mentor you? 5. What are the responsibilities of the mentee in the mentoring process?

Figure 9 Simple Listing of Prerequisite Knowledge (*Foundations of Organic Chemistry,* Pre-Market Edition)

Prerequisite Knowledge

Gen Chem	☐	The nucleus of an atom is a minor component of its size with most atomic volume due to electron repulsion
Activity 8	☐	Non-covalent interactions affect physical properties
Activity 10	☐	Approximate bond angles in a molecule are based on VSEPR theory
	☐	Hybridization of atomic orbitals determines bond angles within a molecule
Activity 11	☐	IUPAC systematic names are used to identify straight, branched, or cyclic alkanes, alkyl halides, and alcohols

Figure 10 Performance-Based Listing of Prerequisite Knowledge (*Foundations of Organic Chemistry,* First Edition)

Prerequisite Knowledge

I am ready for this activity because I can...

...explain why the nucleus of an atom is a minor component of its size with most of its atomic volume due to electron repulsion.

☐ **Yes!** ☐ ***No*** ⟶ Review your general chemistry text or do a web search.

...determine types of intermolecular forces a molecule will have and explain how they affect its physical properties.

☐ **Yes!** ☐ ***No*** ⟶ Review Activity 8: WGAD #3, #5, SYK #1, #2

...use VSPER theory to predict bond angles and geometry in a given molecule.

☐ **Yes!** ☐ ***No*** ⟶ Review Activity 10: SYK #1, #2

...determine bond angles in a molecule using an atoms hybridization state.

☐ **Yes!** ☐ ***No*** ⟶ Review Activity 10: CTQ #1, SYK #2

...name an alkane, alcohol, or alkyl halide when given a Lewis structure, condensed structure, or skeletal structure. Conversely, I can draw Lewis structures, condensed structures or skeletal structures when given the name of an alkane, alcohol, or alkyl halide.

☐ **Yes!** ☐ ***No*** ⟶ Review Activity 11: WGAD #1-4, SYK #5

Figure 11

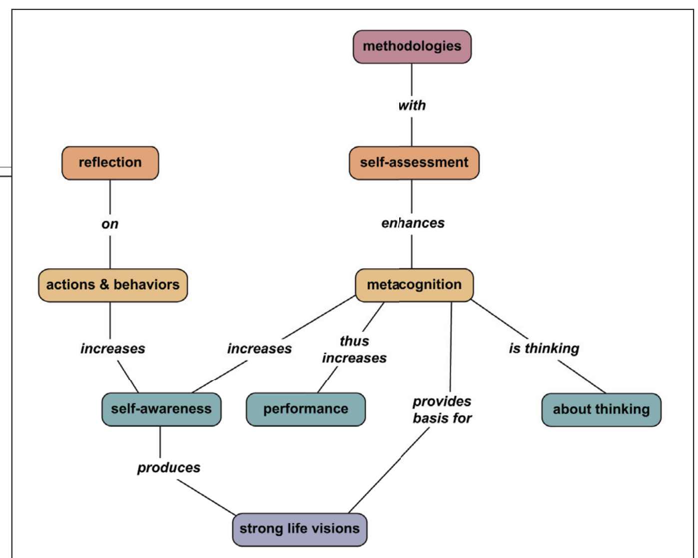
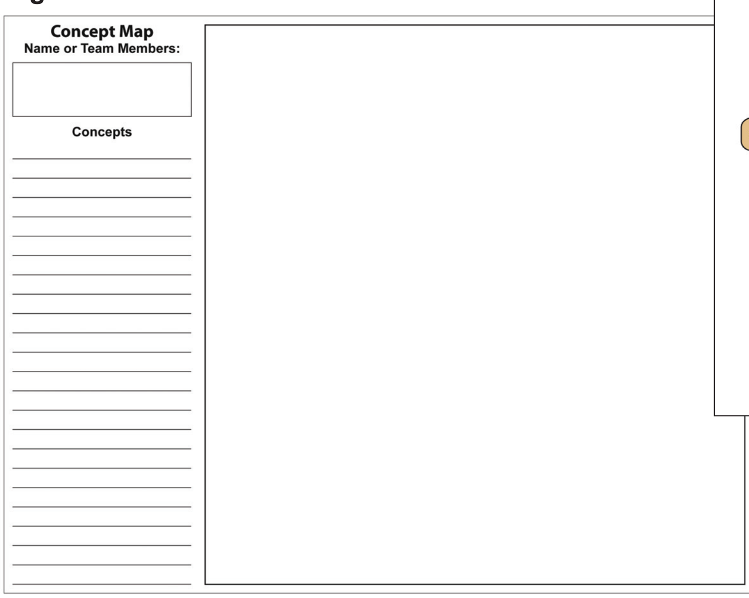


Figure 12



els of concept maps and are then tasked with creating a concept map for either "learning to learn" or "creating self-growth." Students are then prompted to consider how concept mapping improves metacognition in Critical Thinking Questions #7. A blank concept map worksheet is provided to support this work, a tool also provided in the *Student Success Toolbox* (Pacific Crest, 2011) (see Figure 12).

Quantitative Reasoning and Problem Solving (Ellis, Apple, Watts, Hintze, Teeguarden, Cappetta & Burke, 2014) employs a similar strategy, tasking students with completing a concept map for "learning to learn mathematics" in Activity 1.2, Applying the Learning Process Methodology: Math and Metacognition.

As useful as concept mapping and concept maps are in the context of student curricula and learning, their potential efficacy as tools for communication have been explored with respect to the information not only within the Transformation of Education but also in the relationship of the aspects to the larger scholarship and practices of Process Education. In *Concept Maps for Linking Aspects in the Transformation of Education* (Beyerlein, Burke & Hintze, 2012a), three Transformation of Education concept maps were created to serve as models for exploration and learning. The authors explain,

> Once the maps were created, educator ways of being and common teaching and learning toolkits became obvious from each map. The set of concept maps is customized for instructors, rather than learners, to help them better visualize their personal teaching/learning practices and their local teaching/learning culture on the continuum from traditional to transformational environments.

A learning object is available showing not only the concept maps but the methodology used to create them (Novak & Cañas, 2008): http://www.transformation-of-education.com/conceptmaps/ (Beyerlein, Burke & Hintze, 2012b).

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