Higher-Order Thinking Skills: Using Knowledge

Making Use of Information
In 1929, the philosopher Alfred North Whitehead invented the term “inert knowledge” to describe the mindless accumulation of facts without purpose. David Perkins (1995) described inert knowledge as the “knowledge equivalent of a couch potato” (p. 22). It just sits around taking up space. The purpose of knowing things is, after all, to do something with what we know.

This point of view is especially important in project-based learning. It is also important in the integration of technology when students use technology to learn and to show what they have learned. Marzano’s Knowledge Utilization component of the cognitive processes includes four ways of using knowledge: decision making, problem solving, experimental inquiry, and investigation.

Although teachers often worry that an emphasis on using knowledge rather than basic skills will result in lower test scores, a synthesis of research studies conducted by the George Lucas Foundation (2001) found that in many cases, the opposite was true. Students who studied mathematics through projects scored as well, or, in some cases, even better, than their counterparts who participated in more traditional learning activities.

Decision Making
The process of decision making is used when a person has to decide between two or more choices. Within a project activity students will be called upon to use this process frequently as they choose topics, resources, and methods of presentation.

Problem Solving
Problem solving occurs when students encounter a challenge or obstacle to the completion of a goal. Due to the complex nature of most projects, students in project-based learning classrooms must be expert problem solvers.

Experimental Inquiry
Experimental Inquiry is a particular type of using knowledge because it is governed by accepted rules of method and evidence. The most widely known type of experimental inquiry is the scientific method. Other types of experimental inquiry are experiments where some kind of treatment (such as a teaching method) is given to one group of children and withheld from another. This type of using knowledge has strict guidelines regarding the kind of evidence that is accepted, how this evidence is collected, and how conclusions are reached.

Investigation
Investigation is the process “of generating and testing hypotheses about past, present, or future events” (Marzano 2000, 47). Investigation is like experimental inquiry in some ways, but it differs in its methods and kinds of evidence. People do not directly observe and collect data in an investigation. They get their information from the writings and experiences of others. The conclusions of an investigation are judged based on the strength and logic of their arguments.

It is important to remember that the cognitive skills of decision making, problem solving, experimental inquiry, and investigation, do not correspond directly to specific projects. A project, such as one in which primary children study different species of bears and use what they learn to develop a children’s guide to the bear section of the zoo are using problem
solving, decision making, and investigation cognitive skills. The practice of these complex thinking strategies are based on lower-level skills such as analysis, comprehension, and retrieval.

**References**


Decision Making

Making Good Choices
Decision making is an important skill in life. We make hundreds of decisions a day. Most are trivial and have no lasting impact on our lives while others can be life-changing. All educators strive to help students become good decision makers.

Marzano (2000) describes the steps of good decision making:

1. Think of as many alternatives as you can.
2. Think about the good and bad points of each alternative.
3. Think about the likelihood of success of the best alternatives.
4. Choose the best alternative based on its value and likelihood of success.

Perhaps, the most important stage of decision making is the first one, coming up with alternative responses. People often fail to consider all the possible alternatives when contemplating a decision. They think, "I can do x or I can do y," never thinking that there might also be a possible z or a, or b or even a 1a or a 2b (Swartz 2000). Important decisions are rarely simple, and the best alternative may only come after careful deliberation. Brainstorming is one technique for generating a large number of alternative responses for decisions.

Once a group of reasonable alternatives has been collected, good decision makers must weigh the benefits and drawbacks to each one in order to make a sound choice. Knowledge plays an important role in this stage of making decisions. Having complete information is essential to making a good decision.

Immature students often focus on only short-term consequences and also may fail to consider the effect their choices will have on others. It is also a characteristic of human nature that once we come to a decision we think is reasonable, we are unlikely to seriously consider a better one that may come to our attention. We may in fact refuse to accept any evidence that does not support our decision, even if it is credible (Langer, 1989). “Premature cognitive commitments are like photographs in which meaning rather than motion is frozen” (Swartz, 2000, p. 55).

Teaching Decision Making
Traditionally, many teachers have claimed they were “teaching” their students decision making by giving them decision-type problems to solve. This method has been found to be the least effective in helping students learn skills for making good decisions (Swartz).

Effective instruction in making decisions involves specifying a skill to emphasize in a learning activity, or stage of a project. Many different skills may be appropriate, but teaching one skill at a time in depth will produce greater results. Swartz recommends asking oral questions as students work on decisions, having them work in small groups, making graphic organizers to guide them in the process, and asking them to describe and reflect on their strategies during and after making the decision. Skills taught in this way are likely to transfer to new situations if students are reminded of the strategies they have studied in the past when they confront new decisions.

Examples of Teaching Decision Making
In the Unit Plan, Teacher’s Pet, young children study different animals and their habitats in order to choose a new pet for the teacher. This unit provides many opportunities for a teacher to discuss aspects of good decision making. As the students propose possible pets, they can be prompted to think about the long-term consequences of choosing different pets.

- How big will the pet grow to be and how big of a pet can the teacher have?
- What kind of a habitat does the pet need? Can the teacher provide the right habitat? What would happen to the pet if it lived for a long time in the wrong habitat?
- What kind of care does the pet need? Can the teacher give it the right care? What would happen to the pet if it lived for a long time without the right kind of care?
Middle school students think about what makes a hero in the unit *Enduring Heroes*. This unit gives students the opportunity to think about values and goals in terms of contemporary heroes. This unit can show how different people make different decisions based on their personal values and beliefs. Teachers can ask students to think about what values their proposed heroes represent and then give them explicit instruction in how to match those values to their own.

Senior world-language students choose a country to visit in the unit *¡Vamonos!* While students are working on this project, the teacher can highlight different aspects of their decision to select a country, emphasizing making decisions that involve a complex network of considerations, such as climate, recreation, dialect of the language, personal preferences, and so forth. Helping students remember to consider the wide range of factors and the short- and long-term consequences of their choices is a skill that can be transferred to other projects in school and in life.

A word of caution to teachers who want their students to be better decision makers. Some programs give students a list of specific steps to go through when making decisions. This may not be the best way to teach the skills. Decisions are not always linear, and some students, depending on their personalities or thinking styles, may reject a rigid process, which may cause them not to think about their decisions at all. Help students find a way that makes sense for them and that helps them take into account all the information that they need to make a good decisions. The ways of doing this can be different depending on the learning and thinking styles of each student. Helping students devise methods that are flexible and practical makes it more likely that students will use them on their own.

**References**


Problem Solving

Creating Solutions
Problem solving takes place whenever we are confronted with a barrier or challenge to achieving a goal. Problems can be simply solved, such as sharpening a pencil when the tip breaks, or can take years and input from hundreds of experts, such as coming up with a solution to global warming. Problems can have social, cultural, political, and personal dimensions. Some problems may have dozens of good solutions, and some may have only a few poor solutions. What is a serious problem for one person may not be a problem at all for another. In all cases, solving problems is part of learning and part of life.

Knowledge is extremely important for solving problems, because information is the fuel that leads us to success. Anyone can relate to being stuck with a problem, such as a plugged up sink, a screaming child, or a stalled car, knowing that the problem is solvable, but just not having the information needed to solve it.

Facione (1999) describes a list of characteristics of good problem solvers developed by experts in critical thinking. These people show

- Clarity in stating the question or concern
- Orderliness in working with complexity
- Diligence in seeking relevant information
- Reasonableness in selecting and applying criteria
- Care in focusing attention on the concern at hand
- Persistence through difficulties are encountered
- Precision to the degree permitted by the subject and the circumstances

Wilson, Fernandez, and Hadaway (1993) add that those who are proficient at mathematical problem solving are aware of a variety of processes that they can use and also have the ability to invent new strategies when they encounter unexpected situations.

Problem Solving Processes
Problem solving begins with the identification of a problem. Specifying and describing a problem may be more of a creative process than an analytical one, since this stage requires the ability to see how things could be different. For example, Teri Pall, who invented the cordless phone in 1965, thought that it would be possible to talk on the phone while moving about the house. This took as much imagination as it did technical know-how.

Cognitive processes are also important in problem solving. Anderson and his colleagues (1999) explain how different thinking skills contribute to the resolution of a problem.

- *Comprehension* helps learners make a visual representation of the problem.
- *Remembering* helps people call up the information and procedures they will need.
- *Synthesis* helps them organize the knowledge they have gathered into a structure that will be most useful and efficient.
- *Evaluation* is used to decide which methods to use and whether these methods have worked.
- *Metacognitive strategies* help problem solvers set goals, make plans, change strategies in mid-stream if they need to, and make decisions about the success of the solution.

Technology and Problem Solving
The use of computer technology as a tool in problem solving has become more widespread as computers have become more sophisticated and available. A variety of types of software help users portray problems graphically. Computer-based communication can provide learners with access to the information they need to produce solutions. It can also place students in contact with experts who can offer them strategies and encouragement.
Some kinds of computer games can provide students practice at understanding a problem, finding and organizing necessary information, developing a plan of action, “reasoning, hypothesis-testing and decision making,” and building awareness of different kinds of problem-solving tools (Wegerif, 2002, p. 28).

Wegerif (2002) eloquently describes the role that technology can play in solving problems:

Before the arrival of computers in human history it seemed natural to many to describe ‘higher order thinking’, or rationality, in terms of abstract reason on the model of formal logic or mathematics. This kind of thinking was really hard, potentially very useful and only a few people could do it well. Computers, however, find formal reasoning very easy. What they find hard is the sort of things most people take for granted like coming up creatively with new ways forward in complex, fast-changing and open-ended contexts where there is no certainty of being right. One way in which thinking skills are related to developments in technology is therefore simply that the human skills that we value most, and that are rewarded the most, are those skills that computers cannot yet imitate.

Teaching Problem Solving

In order for students to develop into expert problem solvers, they must first encounter problems that engage them and give them opportunities to develop the skills they need to learn. Through project-based learning, students have direct experience solving problems.

The types of problems that benefit students the most are the ones that perplex them. For a problem to have the most benefit for students it must be challenging enough to require the regulation of cognitive and metacognitive strategies.

One way in which teachers can improve students’ problem-solving skills is by having them focus on processes rather than outcomes. Dr. Ellen Langer, psychology professor, points out that thinking of outcomes often inhibits students in problem solving. A process orientation, thinking “How do I do it?” instead of “Can I do it?” helps them think actively of different ways in which a problem might be solved instead of focusing on the many possibilities for failure (Langer, 1989, p. 34).

A group of researchers in math education emphasize the importance of reflection during problem-solving activities. “It is what you learn after you have solved the problem that really counts,” they explain (Wilson, Fernandez, & Hadaway, 1993). However, they warn that developing the desire to look back in students is very difficult. This is due, in part, to the specific culture of many mathematics classrooms in which the purpose of solving a problem is just to find the answer, not to learn problem-solving skills.

Reflection can occur in classrooms in both formal and informal ways. Providing time just for writing or talking about the processes they used to solve problems can help students refine their own processes. There is also considerable research to support the notion that students improve their problem-solving skills by working in groups (Wegerif, 2002). These social situations provide them with natural ways of discussing how work on a project is progressing.

It is tempting to provide students with a heuristic, or a rule of thumb, when solving problems. For many teachers and students alike, a left-brain process like following a series of steps when confronting a challenge seems like a logical way to approach a problem. Teachers must bear in mind, however, the many ways in which students’ thinking and learning styles differ. There is considerable evidence that the right brain plays a significant role in solving problems by imagining alternatives, viewing the whole picture, and assigning value to alternative solutions.

Huitt (1998) suggests that, along with the critical and evaluative processes that are so important in problem solving, there is a second group of skills that “tended to be more holistic and parallel, more emotional and intuitive, more creative, more visual, and more tactual/kinesthetic.” He argues that successful problem solvers are creative as well as logical. Both ways of thinking are critical to success. In fact, creativity is often thought to be a special kind of problem solving process.

There are few skills as important for students to learn as problem-solving skills. Young people who can
identify problems that can be solved, explore options for solutions, use appropriate thinking strategies, and manage the whole process metacognitively, are equipped for success in school, in the workplace, and in life.

**Examples of Problem Solving**

Problem solving is such a critical skill that it is difficult to imagine an authentic situation in which students would not be practicing it. Settling disputes on the playground, working through a disagreement with a friend, arguing with a teacher over a grade or with parents over a curfew, are the kinds of problems students must solve in their everyday life. In any kind of complex activity or project, there are also countless problems to be addressed, such as issues with technology, irresponsible group members, inadequate materials, and so forth.

Some projects, however, are built around the solving of big, important problems, often connected in some way to the community. In the Unit Plan, *Go-Go Gadget: Invent a Machine*, students identify work they want to perform, and invent a labor-saving machine to do the job. To help students improve their problem-solving skills during this unit, a teacher could offer mini-lessons on brainstorming, using drawing software to represent a problem, or modeling how to explain thinking processes to others.

In the Unit Plan, *Don’t Trash the Earth*, middle school students turn trash into treasure as they divert materials from the waste stream and turn it into attractive merchandise they sell at a holiday business fair. Solving this problem requires the collection and analysis of data as well as creative thinking. A teacher could provide students with explicit instruction in the use of databases, the generation of numerous alternatives, and creatively thinking of uncommon uses for common waste materials.

In the Unit Plan, *Composting: Why Bother?*, high-school adolescent students also address the topic of the environment when they engage in the entire process of making new material from waste, as they turn biodegradable garbage into the gardener's "black gold" or rich compost. In this unit, students have the opportunity to practice problem solving as they compete to get organic material to decompose rather than rot. They sell compost for a classroom fundraiser. By having students stop periodically and reflect on the problems they have encountered and how they addressed them, teachers can support the transfer of skills used in one context to other similar situations.

**References**


Experimental Inquiry and Investigation

Creating Knowledge
Experimental Inquiry is a special kind of problem solving that is governed by rules of process and evidence. Marzano (2000) describes experimental inquiry as a "process of generating and testing hypotheses for the purpose of understanding some physical or psychological phenomenon" (p. 57).

The most well-known type of experimental inquiry is the “scientific method,” a way of answering questions about nature. There are six steps to the scientific method.

1. State a question or a problem.
2. Gather some information that is relevant to the problem.
3. Create a hypothesis that explains the problem.
4. Test the hypothesis by conducting an experiment or collecting more information.
5. Abandon or modify the hypothesis to fit with the results of the experiment.
6. If the hypothesis is found to be true or not true, “construct, support, or cast doubt on a scientific theory” (Shafersman, 1997).

Investigation is a way of using knowledge that is similar to experimental inquiry. It is “the process of generating and testing hypotheses about past, present, or future events” (Marzano, 2000, p. 47). The definitions of these two processes may sound like they describe the same kind of thinking, but there are significant differences.

Experimental Inquiry
Experimental inquiry is built on empirical evidence. This is evidence that can be examined through the senses. Theoretically, there should be no disagreement about what empirical evidence says because it looks the same to everyone. The fact that the sun rises in the east is empirical evidence. People may disagree about why it rises in the east, but few would quibble with the fact that it does. The children measuring bean plants in the Unit Plan, The Great Bean Race, are collecting empirical evidence by measuring their bean plants. Scientific thinking requires that people figure out what kind of empirical evidence they need to prove or disprove their hypotheses.

A high-school psychology student may hypothesize that students who start school later in the day get better grades than those who start early. She can collect the empirical evidence of which students take early classes, which ones take late classes, and what their grades are. These are facts and no one could disagree with what she finds out. Like a student who measures a shadow at different times of the day, the numbers she finds are empirical evidence.

Now, of course, other things will need to be figured into experiments. Maybe in the high-school study, all the smart kids take early classes, or maybe just by coincidence this semester there happen to be a lot of good students who start school late in the day. Maybe the child measuring shadows is measuring them on a cloudy day where he can’t really see the edges clearly or maybe the tool he’s using to measure has blurry marks on it. All kinds of factors must be considered in experimental inquiry, and scientists and others who do this kind of inquiry know what the rules are. They know there is a right way to go about collecting and analyzing evidence. And that is what makes what they do officially experimental inquiry.

Investigations
In an investigation the students are not observing nature directly or collecting their own evidence. They are interviewing people, examining documents, and reading what others have said about a topic. Then they draw some conclusions based on what they have learned.

Just because they are not collecting original evidence does not mean that the quality of the evidence is not important to them. They need to be careful to use reliable sources and truthful information. What students have after performing this kind of process is not a scientific theory. Rather it is an argument.
For example, a sixth grader is investigating the Battle of Little Big Horn. He reads several accounts by Native Americans and by soldiers. He also reads biographies of General Custer and Sitting Bull. After he has collected all this information, he makes some conclusions about what happened there. His conclusions must follow the rules, not of the scientific method, but of good argumentation. His opinion about the Battle of Little Big Horn must be supported by credible evidence and follow the standards for good reasoning. The *Showing Evidence Tool* can help students form good arguments.

Both kinds of inquiry are important in the classroom, but some are more appropriate for different subject areas and different topics. For example, students do not have access to the kinds of equipment necessary for many types of scientific experiments, but they can devise experiments using the natural materials they find around them. On the other hand, many historical, social, and political topics can be understood best through investigation, bearing in mind that there are also rules about drawing conclusions in these areas, too.

**References**

Creativity

Innovation and Ingenuity
Most educators would agree that creativity is generally a good thing. Yet few teachers have a clear idea of what creative student work looks like or what they can do to improve students’ creativity. Fortunately, there is research to help in this area. Creativity is something that all of us have to some degree, and there are techniques teachers can use to help students become more creative.

According to Robert Sternberg, a nationally-respected researcher on the subject, “Creativity is the ability to produce work that is both novel and appropriate” (cited in Armstrong, 1998, p. 3). Highly creative individuals like Pablo Picasso and Albert Einstein have changed the face of the fields they work in by their fresh perspectives and original ideas. For the rest of us, however, “a thought would be considered creative if it is novel to the one who produces it, irrespective of how many others may have entertained that thought” (Nickerson, 2000, p. 394).

Children can be creative in many ways, by seeing new relationships that surprise their classmates and deepen a discussion. By “giving an example, giving a counter-example, questioning, proposing a solution, creating new relationships, providing context, inventing a problem” students can use their creativity to enrich their learning and the learning of others (Daniel, Lafortune and Pallascio, 2003, p. 18).

Creativity takes many forms in children such as a first-grader’s surprise ending to a story about her stuffed animals, a fifth-grader’s plan for sharing playground equipment fairly, a high-school junior’s robot, and a biology student's method for rebuilding the habitat of a local bird. Creative endeavors like these benefit both the individuals who perform them and the society which nurtures them.

Helping students develop their creativity is a worthwhile goal if for no other reason than personal enhancement. A poem that is only read by the poet, an idea to make housekeeping more efficient, an insight into the world around us, may not be known to anyone, but still has the power to make life more meaningful and more pleasurable. Teresa Amabile (1983) argues that anyone with normal intelligence can aspire to be creative in some area, and everyone benefits from the “excitement and color” (Nickerson 1999 400) these creative accomplishments add to our lives.

While having “excitement and color” in our lives is certainly a worthy goal, most of us live in a real world, where we are held accountable for very different outcomes with our students. Why worry about improving students’ creativity when success is judged on the basis of academic learning and test scores? Sternberg and Lubart (1999) provide comforting news. They claim that research shows that when creative students are taught and assessed in ways that value their creativity, their academic learning also improves, so teaching to improve creativity can do more than make a person happier and more productive in society. It can also help students improve their test scores.

Components of Creativity
People often tend to think of creativity as magical and mysterious. Certainly there is something strange and wonderful about the creation of a great work of art or an earth-shattering idea. Those who study creativity, however, believe that extraordinary products are made through essentially ordinary thinking processes, which means we can all develop our creativity to some degree.

Creative individuals possess a combination of intellectual abilities, personality traits, and subject-area knowledge. They have the cognitive ability to deal with complex situations, have a set of tools they can use to generate many ideas, and are able to concentrate completely on a task (Amabile 1983). According to Sternberg and Lubart (1999), creative individuals have what they call a “synthetic ability” to see problems in novel ways, an “analytic ability” to decide which ideas are worth following through on and which aren’t, and the ability to convince others that their ideas are worthwhile.

Creativity is more than just the brain, however. People who are very creative also have personality and character traits that contribute to the production of unusual and appropriate solutions to problems. Two of the most important traits are the inclination to take sensible risks and the ability to tolerate high levels of confusion and ambiguity (Sternberg and Lubart 1999).
There has been a great deal of discussion about the relationship between curiosity and flexibility. Being creative requires being able to see things from different perspectives and changing your point of view when the situation demands it. People who are creative also have self-efficacy, and believe in their ability to accomplish difficult tasks and are persistent at overcoming obstacles.

Very creative people are often thought to be highly intelligent. While this is occasionally true, evidence shows that the connection between intelligence and creativity is not straightforward. Sternberg and O'Hara (1999) found people with low IQs are not likely to be exceptionally creative but above 120, there is no correlation between traditional intelligence and creativity. They even suggest that individuals with very high IQs may be rewarded so much for their analytical thinking that they do not reach their creative potential.

Technology and Creativity
In her 2002 review of the literature on creativity and technology, the educator, Avril Loveless, explains the complicated relationship between creativity and technology. Tools such as digital audio, video devices, and computers can contribute to creative processes in a variety of ways. She explains that the features of technology such as provisionality, interactivity, capacity, range, speed, and automatic functions, allow students to do things that they could not do, or at least could not do as efficiently, without technology.

Because computers allow students to make changes and try out alternatives and keep track of how well they work, they are useful for revising and editing. The interactivity of computers allows users to receive and give feedback from processes or other individuals. Technology gives students access to great amounts of information that would have been unimaginable just a few years ago. Because computers can perform complex operations easily and quickly, users can put their efforts into more high-level processes such as the analysis, interpretation, and synthesis of information.

In the classroom, teachers can use technology to help students to brainstorm and evaluate ideas, make connections, collaborate, and communicate. They must remember, however, that it is not the access to technology that encourages creativity, but the creation of an environment in which technology can be used to accomplish goals in creative ways.

Teaching Creativity
Some people may argue that it is impossible to teach creativity, that it is an innate quality like musical talent. However, like a talent, people can work to make themselves more creative, and teachers can help their students develop their creativity.

The classroom environment has a big impact on the development of creativity in students. Some suggestions for creating an environment that encourages creativity in a project-based classroom are:

- Have a variety of materials and equipment available
- Reduce the negative consequences of risk-taking
- Expose students to a wide range of creative products
- Make available resources on a wide range of topics so students can find something that interests them and sparks their imagination
- Allow flexibility in time and classroom arrangement
- Encourage students to collaborate on projects
- Make sure that students have some quiet time during project work because noise can inhibit creativity
- Connect students with creative individuals in the community
- Set an example by thinking creatively yourself and sharing your products, your processes, and your joy in your accomplishments

Success in any aspect of education is linked to student motivation. Research indicates that intrinsic motivation enhances creativity while extrinsic motivation generally undermines it. (Amabile 1983). Competition for prizes for the “best” product has a detrimental effect on creativity, possibly because
the energy and commitment necessary to produce novel ideas takes a great deal of effort, which extrinsically motivated individuals are unlikely to expend (Collins and Amabile 1999).

The issue is not black and white, however. Different kinds of motivation may be effective at different stages of the creative process. While students are exploring a problem and trying to think of ideas, they may be intrinsically motivated. On the other hand, extrinsic rewards may encourage students to learn the skills they need to complete a task or to persist when the initial enthusiasm wears off (Collins and Amabile 1999).

Research has shown that explicit instruction in strategies that produce creative products can help students become more creative (Runco and Sakamoto 1999). Strategies such as brainstorming, exploring multiple options, and evaluating validity, can be taught and assessed in a variety of ways and contexts. Forcing students to compare unlike concepts can also bring out creative responses.

Teachers must take care with the use of examples of finished products. Although providing students with examples is generally considered to be beneficial, participants in a research study created products that contained features of the examples even when they were specifically told to create something as different as possible from the example (Ward, Smith and Finke 1999). It may be more useful to provide students with examples of processes that experts use than with examples of possible products.

All students have a creative potential within them. Whether they realize that potential depends only partly on their motivation and ability. By using language that encourages creativity and creating an environment which challenges and supports students in their creative efforts, teachers can help students think and act more creatively.

References


