Designing Effective Technical and Procedural STEM Learning Experiences

Imagine giving a group of fourth graders a collection of materials and asking them to construct a working electrical circuit. Some students immediately begin experimenting, while others struggle to understand where to start. A few connect components incorrectly, and others become frustrated when their circuits fail to work.

Now imagine providing those same students with carefully developed technical directions that guide them through constructing a simple circuit. Students learn how the components function, practice using the materials correctly, and develop the foundational knowledge necessary to eventually design their own electrical systems.

This illustrates the value of technical and procedural STEM learning experiences. Although engineering design challenges encourage students to develop original solutions to open-ended problems, procedural experiences help students acquire the knowledge, skills, and confidence necessary to work with STEM concepts, tools, and technologies.

What Is a Technical or Procedural STEM Learning Experience?

Technical and procedural STEM learning experiences are structured activities in which students follow a defined sequence of steps to complete a task, construct a product, or demonstrate a particular process. These experiences typically have an identifiable outcome and require students to apply knowledge, use tools and materials appropriately, and follow directions accurately.

Procedural learning differs from engineering design in several important ways. In a procedural experience, students are generally provided with the steps necessary to achieve a particular outcome. In an engineering design challenge, students are presented with a problem and must develop, test, and improve their own solutions.

Well-designed procedural experiences can reduce unnecessary frustration, promote independence, and allow students to focus on important STEM concepts rather than struggling to understand what they are supposed to do. However, developing effective technical directions requires careful consideration of the learning objectives, the students' prior knowledge, and the level of structure necessary for successful learning.

For example, consider two activities involving KEVA Planks or Legos.

Procedural STEM Experience: Students follow illustrated directions to construct a specific bridge configuration. Through this process, they practice measuring, aligning components, following technical directions, and understanding how structural elements contribute to stability.

Engineering Design Experience: Students are challenged to design and construct a bridge that spans a specified distance while supporting a particular load, using a limited number of KEVA Planks. Students must develop their own solutions, test their structures, evaluate their performance, and make improvements.

Although both activities involve the same materials and may address similar STEM concepts, the learning experiences are fundamentally different. One emphasizes following a defined process and developing technical skills, while the other emphasizes problem-solving, decision-making, creativity, and engineering design.

Neither approach is inherently better than the other. Both have important places in elementary STEM education. In fact, procedural learning experiences can provide the foundational knowledge and technical skills that students need to engage successfully in more complex engineering design challenges.

When Should Teachers Use Procedural STEM Learning Experiences?

Technical and procedural experiences are particularly valuable when students are learning unfamiliar processes, developing new technical skills, or working with tools and materials that require specific methods of use.

For example, students may need explicit procedural instruction when learning to construct an electrical circuit, operate a programmable robot, use measurement tools, or safely work with fabrication equipment. In these situations, providing clear directions helps students develop competence and confidence while reducing errors and unnecessary frustration.

Procedural instruction is especially useful when a task or process:

- Involves unfamiliar tools, materials, or technologies.
- Requires students to follow a particular sequence of steps.
- Includes important safety considerations.
- Demands accuracy, consistency, or careful measurement.
- Involves a complex process that can be broken into manageable steps.
- Introduces technical knowledge or skills that students will use in future learning experiences.
- Requires documentation, data collection, or consistent testing procedures.

However, teachers should carefully consider whether a prescribed procedure is necessary. Providing students with detailed directions for every aspect of an activity may unintentionally eliminate opportunities for creativity, exploration, and potentially invite design fixation.

For example, if the instructional goal is to teach students how to operate a programmable robot, step-by-step directions may be appropriate. However, if the goal is for students to develop an algorithm that allows a robot to navigate an unfamiliar maze, providing the complete sequence of commands would eliminate much of the intended problem-solving experience.

The important question is not simply whether students need directions, but rather how much direction is necessary to support the intended learning.

How Do Teachers Develop Effective Technical Directions?

Writing effective technical directions requires more than simply listing a series of steps. Directions must communicate what students need to know, in a sequence they can understand, using language and visual representations appropriate for their developmental level.

Well-written directions should be accurate, concise, logically organized, and sufficiently detailed to allow students to complete the intended task with an appropriate level of independence.

The following process can help teachers develop effective procedural STEM learning experiences.

Step One: Identify the Learning Purpose and Gather Information

Before writing directions, determine what students should learn from the experience. Are they developing a particular technical skill, learning to operate a tool, applying a scientific principle, or practicing a mathematical process?

The learning objective should guide the amount and type of information included in the procedure.

Next, gather the information necessary to complete the task successfully. This may involve consulting technical resources, reviewing instructional materials, talking with knowledgeable individuals, or completing the activity yourself.

As you work through the process, identify the essential steps, necessary materials, potential difficulties, and important safety considerations.

Remember that your goal is not to communicate everything you know about the task. Instead, you want to provide the information students need to complete the experience successfully while maintaining their focus on the intended STEM learning.

Step Two: Write Clear, Sequential Directions

Begin by organizing the task into a logical sequence of actions. Each step should communicate what students need to do and, when necessary, how they should do it.

Use clear, direct language and action-oriented statements. Avoid unnecessary words, complicated sentences, and technical terminology that students may not understand.

When technical vocabulary is important to the learning experience, introduce and explain the terms rather than avoiding them entirely.

Consider the difference between these directions:

"Students should ensure that the structural components are appropriately positioned to facilitate the successful completion of the assembly process."

And:

"Place two KEVA Planks parallel to each other, approximately four inches apart."

The second direction is more specific, easier to understand, and more useful to students completing the task.

Effective directions should also account for the developmental abilities of the students. Younger learners may need shorter instructions, familiar vocabulary, and more frequent visual supports. Older or more experienced students may be able to follow more complex sequences with less guidance.

As you develop your directions, consider the following questions:

- Are the steps presented in the correct order?
- Does each step clearly communicate an action?
- Is the language appropriate for the students' age and experience?
- Are measurements, materials, and tools clearly identified?
- Have important safety considerations been included?
- Have unnecessary details been eliminated?
- Can students complete the procedure without constant teacher intervention?

The goal is to provide enough information for students to be successful without making the directions unnecessarily complicated.

Step Three: Incorporate Appropriate Visual Supports

Written directions are not always the most effective way to communicate technical information. Photographs, videos, diagrams, illustrations, and flowcharts can help students understand processes that may be difficult to describe using words alone.

For example, a photograph or video showing the correct placement of electrical components may communicate more clearly than several sentences of written directions. Similarly, a diagram illustrating the orientation of KEVA Planks can help students understand how individual pieces should be arranged.

Flowcharts are particularly useful when teaching students to understand sequences, algorithms, and computational thinking. They allow students to visualize the order of actions and recognize relationships between individual steps.

When selecting visual supports, consider whether they genuinely improve understanding. Images should clarify the procedure rather than simply decorate the page.

Effective technical directions often combine concise written instructions with carefully selected visual representations.

Step Four: Test and Revise Your Directions

One of the most important steps in developing technical directions is testing them before using them with students.

Directions that seem perfectly clear to the person who wrote them may be confusing to someone who has never completed the task.

Ask another person to follow your directions without providing additional verbal explanations. Observe the process carefully. Where does the person hesitate? Which steps are misunderstood? Are important details missing? Do the illustrations communicate the intended information?

Use these observations to revise the directions.

When possible, test the revised directions with someone whose knowledge and experience are similar to those of your intended students.

This process of testing and revision is similar to engineering design. Teachers develop an instructional solution, evaluate its effectiveness, identify problems, and make improvements.

Effective technical directions are rarely perfect on the first attempt. They improve through careful observation, feedback, and revision.

How Can Procedural Learning Lead to Engineering Design?

One of the most valuable purposes of procedural STEM instruction is preparing students to apply their knowledge and skills in increasingly independent ways.

Consider an elementary classroom in which students are learning about concepts related to computation thinking - decomposition, pattern recognition, abstraction, and algorithm design.

Initially, students might follow a series of directions to program a code and go mouse bot to move forward, turn, and stop. This structured experience introduces the relationship between programmed commands and the mouse bot's physical movements.

Next, students might be asked to predict the mouse bot's movements based on a particular sequence of commands. They could also identify errors in an existing program and determine how to correct them.

Finally, students might be challenged to design their own sequence of commands that allows the mouse bot to navigate a maze constructed from KEVA Planks.

In this progression, students move from following a procedure to applying their knowledge through independent problem-solving.

The procedural experience is not the ultimate goal. Rather, it provides students with the technical knowledge and confidence necessary to engage in more sophisticated STEM learning.

Teachers should intentionally consider how procedural instruction can serve as a foundation for exploration, creativity, and engineering design.

Key Points to Remember

Technical and procedural STEM learning experiences play an important role in helping elementary students develop foundational knowledge, technical skills, and confidence when working with STEM concepts, tools, materials, and technologies.

Effective procedural experiences begin with a clear instructional purpose. They provide accurate, logically organized, and developmentally appropriate directions that allow students to complete meaningful tasks with increasing independence.

However, procedural instruction should not replace opportunities for students to investigate problems, make decisions, develop original solutions, and engage in engineering design.

The challenge for teachers is determining when students need explicit guidance and when they should be encouraged to develop their own approaches.

Technical/Procedural instruction helps students learn how to use tools, materials, and technologies. Engineering design challenges students to use those capabilities to solve meaningful problems. Both are essential components of effective STEM education.

Reflect and Apply

Describe an activity related to STEM problem solving in which elementary students follow step-by-step directions to construct a specific product or complete a particular process (obviously not solving a mathematics problem or creating a peanut butter and jelly sandwich).

How could you modify or extend this activity to provide students with greater opportunities for decision-making, creativity, problem-solving, and engineering design?

What foundational knowledge or technical skills would students need before successfully completing your redesigned experience?