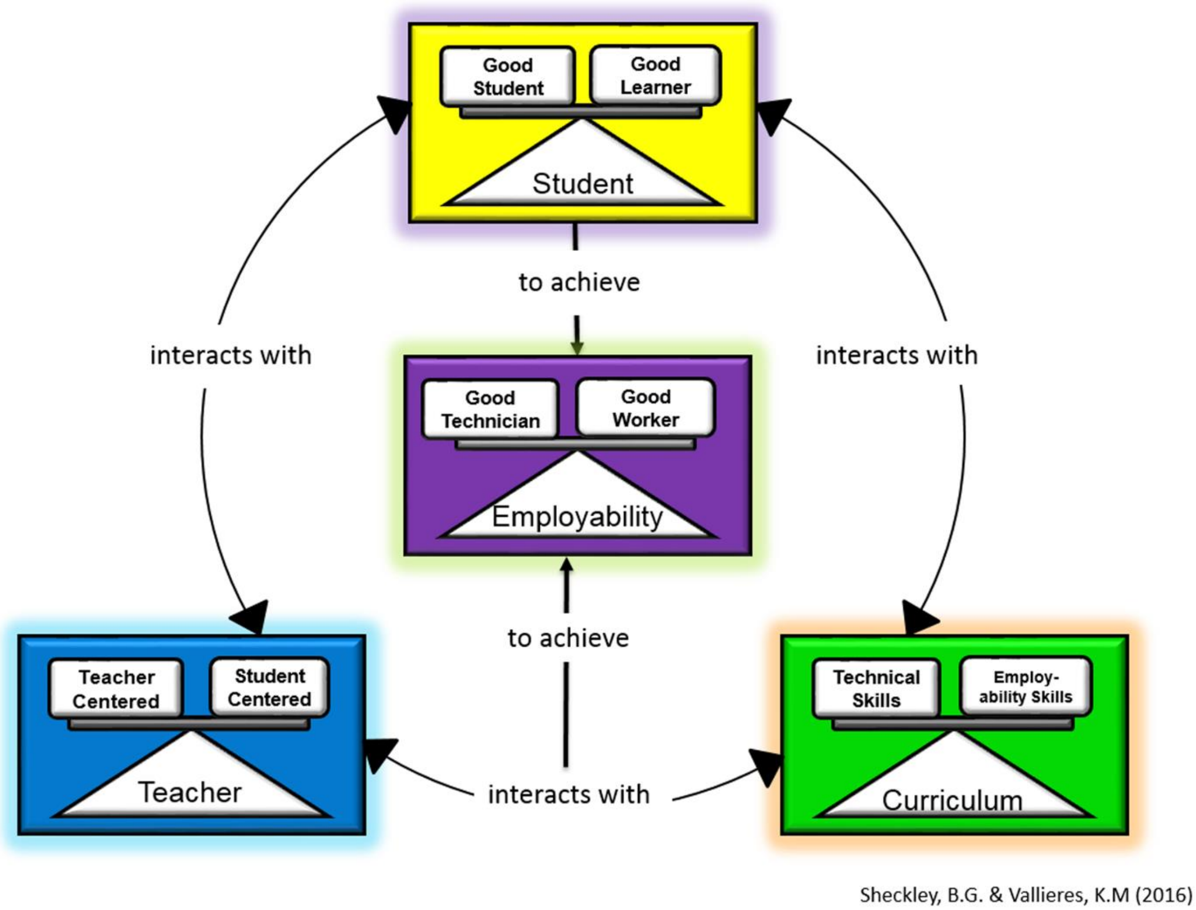
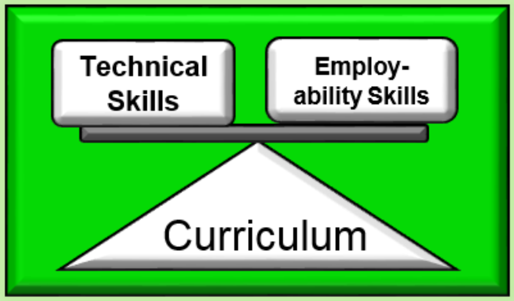
A Balanced Approached to Teaching a Manufacturing Course



A Balanced Approach to Teaching a Manufacturing Course: Curriculum



Topics covered in the role of the curriculum in the learning process

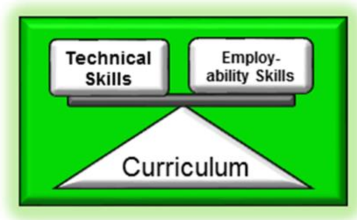
Characteristics of a technical skills verses employability skills

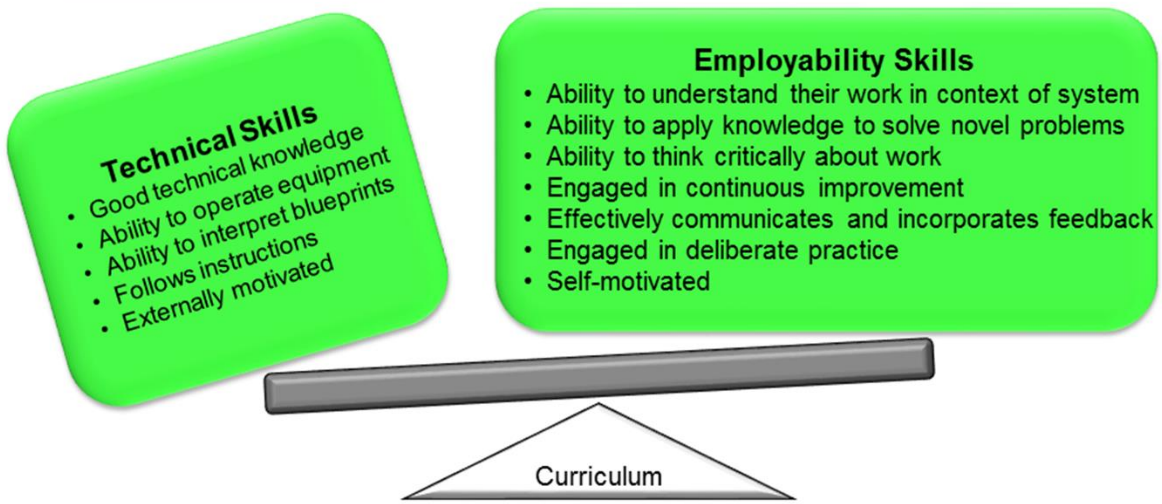
Employability Skills:

- Role of Systems Thinking
- Role of Problem Solving

Objective: To develop and implement teaching practices that will develop students employability skills together with technical skills.

What are the differences between technical skills and employability skills?





Technical Skills	**Employability Skills**
Good technical knowledge Ability to operate equipment Ability to interpret blueprints Follows instructions Externally motivated	Ability to understand their work in the context of the system Ability to apply knowledge to solve novel problems Ability to think critically about work Engaged in continuous improvement Effectively communicates and incorporates feedback Engaged in deliberate practice Self-motivated

According to the Connecticut Business and Industry Association (CBIA) 2014 Manufacturing Survey

"Qualities most lacking among recent hires or attempted hires are overall employability and technical skills (both cited by 60% of manufacturers surveyed).

The basic skill in shortest supply among recent manufacturing job candidates is math, identified by 52% of respondents. Other areas of weakness include writing (28%), reading (26%), and English and computer skills (both 24%).

Aside from employability and basic skills identified in a separate question, we asked Connecticut manufacturers to weigh in on the specific skills most important to their companies' competitiveness.

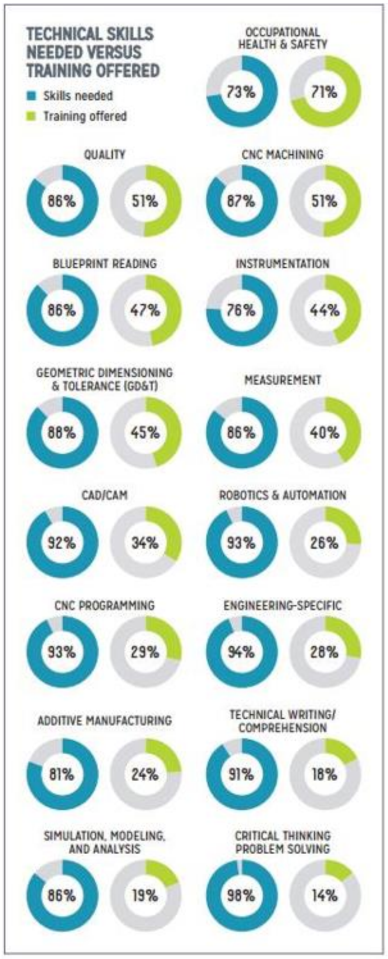
The top answer was critical thinking and problem solving (cited by 98% of respondents), followed by engineering (94%), robotics and automation (93%), CNC programming, (93%), CAD/CAM (92%), and technical writing/comprehension (91%).

Training is rarely offered in these areas; for the most part manufacturers expect the employees they hire to come to the job with these skills".

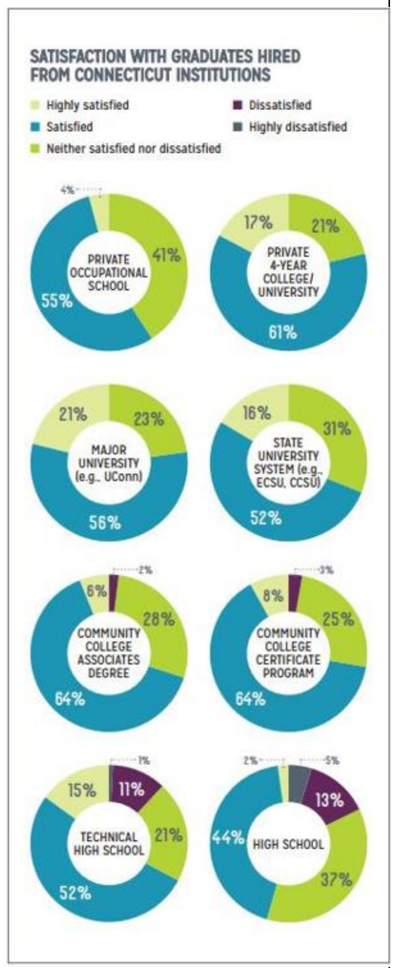
2014 Survey of Connecticut Manufacturing Workforce Needs
(http://www5.cbia.com/newsroom/wp-content/uploads/2014/05/MFG-Workforce_14.pdf?_cldee=YnVkZGpAY2JpYS5jb20%3d&utm_source=ClickDimensions&utm_medium=email&utm_campaign=CD_NEWSROOM)

Manufacturing Survey Continued

Among the businesses surveyed, the greatest barrier to expanding their capabilities in advanced manufacturing technology is not cost or lack of time, but lack of talent.



98% of CT manufacturing businesses state that critical thinking and problem solving skills are skills needed, but only 14% believed that the training is offered in educational programs.



Only 6% of CT manufacturing businesses are highly satisfied with community college associate degree and 8% with certificate program graduates.

Technical Skills Needed vs Training Offered

Skill	Needed	Training Offered	Difference
Occupational Health & Safety	73%	71%	2%
Quality	88%	57%	31%
CNC Machining	87%	57%	30%
Blueprint Reading	86%	47%	39%
Instrumentation	76%	44%	32%
Geometric Dimensioning & Tolerance (GD&T)	88%	45%	43%
Measurement	86%	40%	46%
CAD/CAM	92%	34%	58%
Robotics & Automation	93%	26%	67%
CNC Programming	93%	23%	60%
Engineering-Specific	94%	28%	66%
Additive Manufacturing	81%	24%	57%
Technical Writing/Comprehension	91%	18%	73%
Simulation, Modeling, and Analysis	86%	19%	67%
Critical Thinking Problem Solving	98%	14%	84%

Satisfaction with Graduates Hired from Connecticut Institutes

School Type	Highly Satisfied	Satisfied	Neither Satisfied nor Dissatisfied	Dissatisfied	Highly Dissatisfied
Private Occupational School	4%	55%	41%	0%	0%
Private 4-Year College/ University	17%	61%	21%	0%	0%
Major University (e.g. UConn)	21%	56%	23%	0%	0%
State University System (e.g. ECSU, CCSU)	16%	52%	31%	0%	0%
Community College Associates Degree	6%	64%	28%	2%	0%
Community College Certificate Program	8%	64%	25%	3%	0%
Technical High School	15%	52%	21%	11%	1%
High School	2%	44%	37%	13%	5%

2014 Survey of Connecticut Manufacturing Workforce Needs
(http://www5.cbia.com/newsroom/wp-content/uploads/2014/05/MFG-Workforce_14.pdf?_cldee=YnVkZGpAY2JpYS5jb20%3d&utm_source=ClickDimensions&utm_medium=email&utm_campaign=CD_NEWSROOM)

Unit 2: Systems Thinking

Problem Statements:

What is systems thinking?

What are the learning outcomes (i.e. competencies, skill set) of a good problem based learner that is able to think in terms of systems?

How do these learning outcomes match industry needs?

How do I develop good problem-based learners' ability to think in terms of system that will meet industry demand for good workers?

Objective: To incorporate principals that will support the development of student system thinking skills into course curriculum and teaching practices.

What is Systems Thinking?

"**Systems thinking** [is] a way of **thinking** about, and a language for describing and understanding, the forces and interrelationships that shape the behavior of **systems**."

Peter **Senge's**, The Fifth Discipline Fieldbook

Peter Senge

Systems Thinking: Collective Intelligence

Peter Senge Introduction to Organzational Learning
https://www.youtube.com/watch?v=OpiqnCAQ6S8

James Swanson
Systems Thinking white boarding animation project
https://www.youtube.com/watch?v=lhbLNBqhQkc

Senge's 11 Laws of Systems

In **The Fifth Discipline: The Art and Practice of the Learning Organization**, Senge suggests 11 laws of systems that support that essential understanding:

1. Today's problems come from yesterday's solutions. Leaders are happy to solve problems, but don't always think about intended and unintended consequences. Too often, our solutions strike back to create new problems.

2. **The harder you push, the harder the system pushes back.** Humans have a stubborn tendency to bully our way through tough situations when things are not working out as we would hope. We charge ahead without taking time to think through solutions to find better alternatives. Sometimes we solve problems; more often, especially in the current environment, we find ourselves up to our ears in more problems.

3. Behavior grows better before it grows worse. Short-term solutions give temporary improvement at best but never eliminate fundamental issues and problems. These underlying problems will make the situation worse in the long run.

4. The easy way out leads back in. Leaders often have a few quick fixes in their "quiver" of solutions that have brought quick and easy success in the past. Too often, the easy way out is retrofitting these fixes to any situation without regard to the unique contexts, people and timing.

5. The cure can be worse than the disease. Often, the easy and familiar solution is not only ineffective but addictive and dangerous. It might even induce dependency.

6. Faster is slower. At the first taste of success, it is tempting to advance at full speed without caution. Remember that the optimal rate of growth or change is far slower than the fastest growth or change that is possible.

7. Cause and effect are not always closely related in time and space. We are good at finding causes, even if they are just symptoms unrelated to root causes.

8. Small changes can produce big results — but the areas of highest leverage are often the least obvious. The most grand and splashy solutions — like changing company policy, vision, branding or tagline — seldom work for transforming change. Small, ordinary but consistent and repetitive changes can make a huge difference.

9. You can have your cake and eat it too — but not all at once. Rigid "either-or" choices are not uncommon. Remember that this is not a dilemma if we change our perspective or the "rules" of the system.

10. Dividing an elephant in half does not produce two small elephants. As a leader, failing to see the systems as a whole is at your peril. This flaw in perception and vision often leads to sub-optimal decisions, repeated tasks, lost time and energy, and maybe even losing followers.

11. There is no blame. People and organizations like to blame, point fingers and raise suspicions about events, situations, problems, errors and mistakes. Sometimes we even believe the blame we throw around. Ourselves, the cause of events, situations, problems, errors and mistakes are all part of the system.

Strategic Thinking and Systems Thinking-Backwards Time Machine
(https://backwardstimemachine.wordpress.com/2013/01/08/strategic-thinking-and-systems-thinking/)

Why is Systems Thinking Important?

System thinking enables “people to learn to better understand interdependency and change, and thereby to deal more effectively with the forces that shape the consequences of our actions”. Systems thinking theory includes the role of feedback in understanding and changing systems.

Systems Thinking by Peter M. Senge
http://www.solonline.org/?page=SystemsThinking

“W. Edwards Demming first pointed out the need to understand the system in post-World War II America. Deming stressed that learning must be emergent, designing out the system aspects that are wasteful, sub-optimizing, and unnecessarily redundant.

To improve performance, the system has to change because the system drives 95 percent of any organization’s performance. He also said that any improvement that does not involve human system change methods was doomed to failure in the short-, mid- and long-term; you cannot implement a new system in an old environment and anticipate success.”

Reference - https://backwardstimemachine.wordpress.com/2013/01/08/strategic-thinking-and-systems-thinking/

A Theory of a System for Educators and Managers
https://www.youtube.com/watch?v=2MJ3lGJ4OFo
The Key to Achieving the Necessary Human Mindset Change Lies in Curiosity:

- Ask questions.
- Learn by doing.
- Observe.
- Think about what could be.

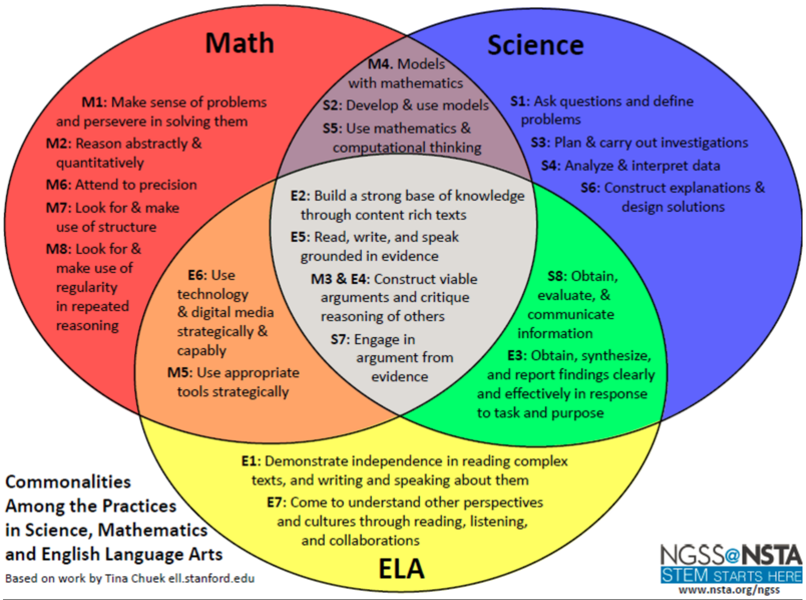
Reference - https://backwardstimemachine.wordpress.com/2013/01/08/strategic-thinking-and-systems-thinking/

Why is Systems Thinking Important for Manufacturing Technicians?

Workplaces are rapidly changing with the consistent evolution of technology and global competition. In order for manufacturers to be completive they must focus on continuous improvement initiatives, lean practices, and reinvestment into advanced technologies. All employees are expected to not only perform the duties of their job, but to contribute to these initiatives. Employees must have the ability to understand their workplace as a complex system, whereby their work is part of the entire process. Changes to one part of the process effects all of the system.

Systems thinking is also connected to problem solving. The root cause of a problem must be determined and understood before a problem can be solved. In many causes the root cause of a problem does not occur where the problem showed up. The root cause is most often associated to a prior operation. To understand how to identify and solve the problem, one must understand the system and how changes to one part of the system will affect all of the system.

Next Generation Science Standard Focus: Systems Thinking



Key Cross-cutting Concepts:

Systems Thinking

- Patterns
- Relationships
- Scale
- Energy conservation
- Structure and function
- Stability and change

5E Approach

- Engage
- Explor
- Explain
- Extend
- Elaborate

Math & Science

Math	**Science**	**Math & Science Together**
M1: make sense of problems and persevere in solving them. **M2**: Reason abstractly & quantitatively. **M6**: Attend to precision. **M7**: Look for & make use of structure. **M8**: Look for & make use of regularity in repeated reasoning.	**S1**: Ask questions and define problems. **S3**: Plan & carry out investigations. **S4**: Analyze & interpret data. **S6**: Construct explanations & design solutions.	**M4**. Models with Mathematics. **S2**: Develop & use models. **S5**: Use mathematics & computational thinking.

Math and English Language Arts

Math	**English Language Arts**	**Math & English Language Arts Together**
M1: make sense of problems and persevere in solving them. **M2**: Reason abstractly & quantitatively. **M6**: Attend to precision. **M7**: Look for & make use of structure. **M8**: Look for & make use of regularity in repeated reasoning.	**E1**: Demonstrate independence in reading complex texts, and writing and speaking about them. **E7**: Come to understand other perspectives and cultures through reading, listening, and collaborations.	**E6**: Use technology & digital media strategically & capably. **M5**: Use appropriate tools strategically.

English Language Arts and Science

English Language Arts	**Science**	**English Language Arts & Science Together**
E1: Demonstrate independence in reading complex texts, and writing and speaking about them. **E7**: Come to understand other perspectives and cultures through reading, listening, and collaborations.	**S1**: Ask questions and define problems. **S3**: Plan & carry out investigations. **S4**: Analyze & interpret data. **S6**: Construct explanations & design solutions.	**S8**: Obtain, evaluate, & communicate information. **E3**: Obtain, synthesize, and report findings clearly and effectively in response to task and purpose.

All Three Together

E2: Build a strong base of knowledge through content rich in texts.

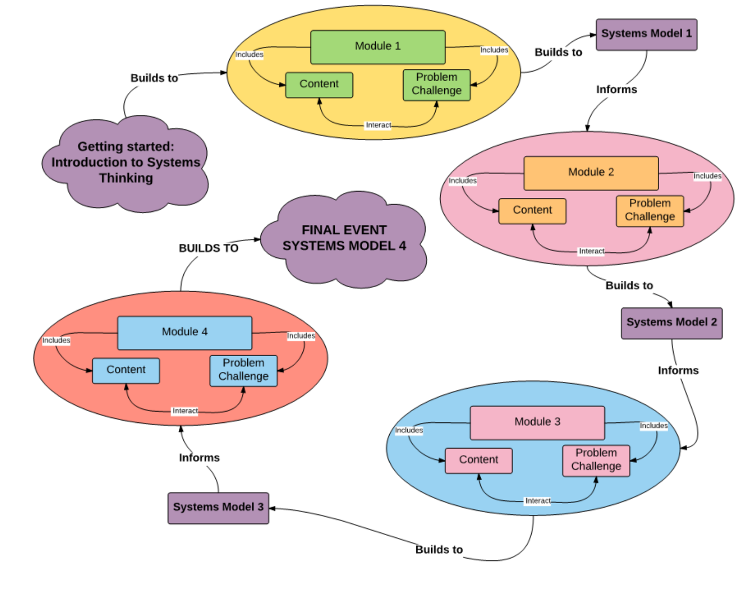
E5: Read, write, and speak grounded in evidence.

Me & E4: Construct viable arguments and critique reasoning of others.

S7: Engage in argument from evidence

Curriculum Perspective

- How can you reframe your course from a series of direct instruction units into a series of problems students can explore?
- How can you structure experiences so students are aware of their thinking – and changes in their thinking?
- How can you emphasize adaptive expertise over efficiency in performance?



A curriculum can be segmented into the following components:
1. Getting started: Introduction to Systems Thinking, which builds to
2. Module 1, which includes
2A. Content, and
2B. Problem Challenge, these build to
3. Systems Model 1, which informs
4. Module 2, which includes
4A. Content, and
4B. Problem Challenge, which build to
5. Systems Model 2, which informs
6. Module 3, which includes
6A. Content, and
6B Problem challenge, which build to
7. Systems Model 3, which informs
8. Module 4, which includes
8A. Content, and
8B. Problem Challenge, which build to
9. Final Event Systems Model 4.

How do I organize my curriculum to balance technical and employability skills within the context of a system?

Identify the Cornerstones of Your Course

Use note cards to organize the technical and employability skills of you course into 3 or 4 integrated units.

Example: Unit 1: Flat Pattern Layout

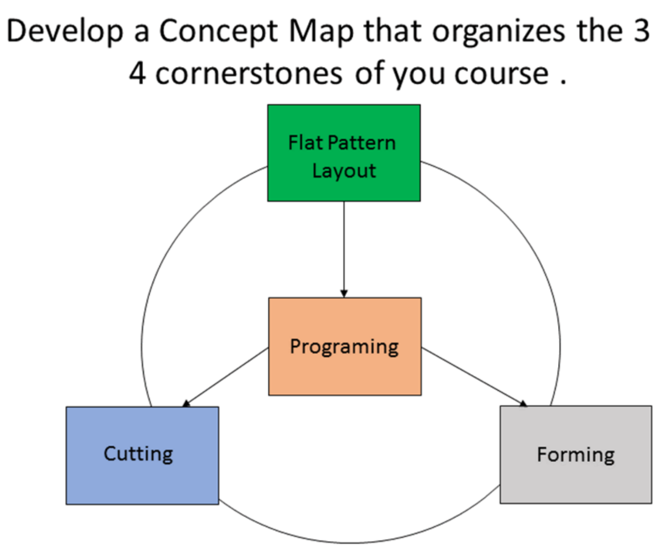
Technical Skills: To interrupt blueprint specifications, understand flat pattern layout for conforming to required tolerances, allowances for forming and paint.

Employability Skills: Understanding how the programing and paint process effects the tolerances and quality. The ability to determine if the part meets specifications and what to do if it does not.

Develop a Concept Map

Develop a Concept Map that organizes the 3 or 4 cornerstones of your course.

Here is an example:



1. Flat Pattern Layout
2. Programming

3A. Cutting

3B. Forming

How do I organize my curriculum to balance technical and employability skills within the context of a system?

For each unit, identify the key principles of good manufacturing practice that represents the ideas contained in each unit.

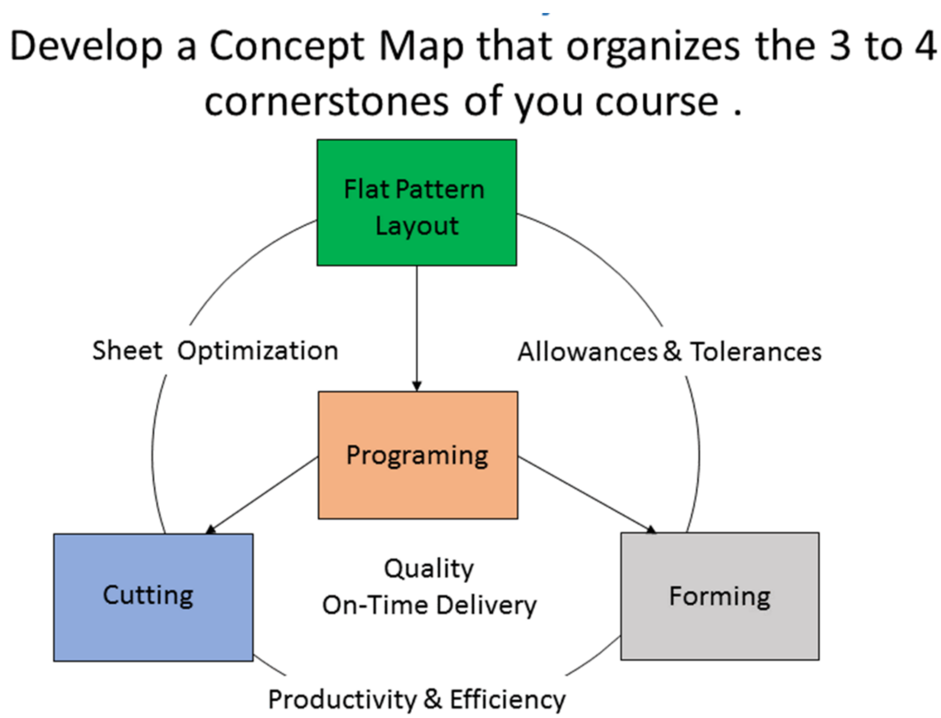
For example: Quality, Lean, Continuous Improvement, On-Time Delivery

Add the good manufacturing practices to the concept map.

Develop a single principle that integrates all the ideas for each unit into a single focal point for the unit.

Add these ideas into your concept map.

For example:



1. Flat Pattern Layout
   Sheet Optimization (as it relates to Flat Pattern Layout and Cutting)
   Allowances & Tolerances (as it relates to Flat Pattern Layout and Forming)
2. Programming
   Quality (as it relates to Programming, Cutting, and Forming)
   On-Time Delivery (as it relates to Programming, Cutting, and Forming)

3A. Cutting
   Productivity & Efficiency (as it relates to Cutting & Forming)

3B. Forming

Develop a Scenario

Develop an overarching or cross cutting problem scenario that students will work on as a means to learn content and employability skills.

Break down the problem scenario into the related units. Develop a series of problems that students can explore as they work to solve the problem scenario.

For example:
Problem Scenario: The last time we worked with Acme we missed the delivery date due to a quality issue found at the press brake. The owner of Acme was not happy. She is coming here next week to make sure that the flat layout of part will meet specifications and the delivery time.
You will have to convince her that your flat layout conforms to specs and will continue to conform once it's completed.

Break down the problem scenario into the related units. Develop a series of problems that students can explore as they work to solve the problem scenario

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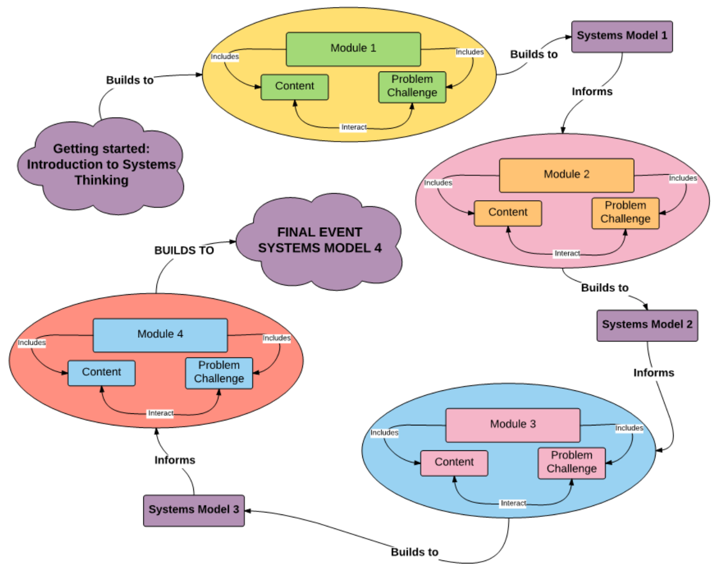
You will have to convince her that your flat layout conforms to specs and will continue to conform once it's completed

Now get to work!

Curriculum Perspective

•How can you structure experiences so students are aware of their thinking – and changes in their thinking? •Consider having students utilize concept mapping as a means to develop systems thinking and problem solving skills. [Lucid Charts](https://www.lucidchart.com/pages/examples/concept-maps) is a free software that can be used to develop concept maps. https://www.lucidchart.com/pages/examples/concept-maps	

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7. Systems Model 3, which informs
8. Module 4, which includes
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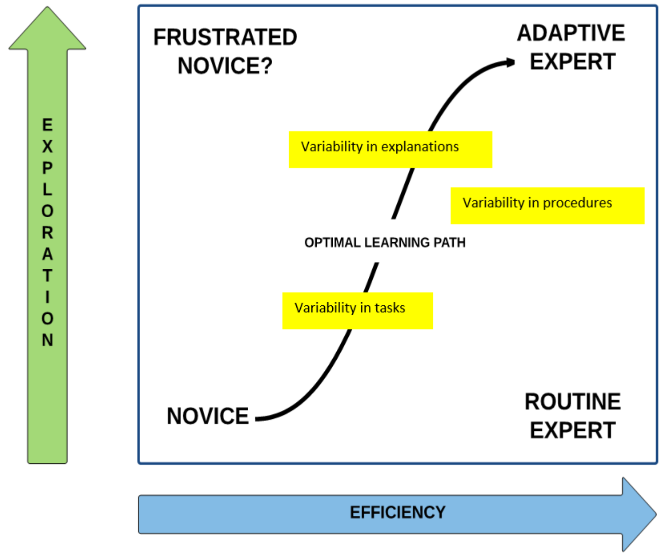
8B. Problem Challenge, which build to
9. Final Event Systems Model 4.

Thinking Systemically: Combining Efficiency and Exploration

An example of exploration in the development of an adaptive expert: [The Piano Player](https://www.youtube.com/watch?v=3qTWHxm5qW0) https://www.youtube.com/watch?v=3qTWHxm5qW0



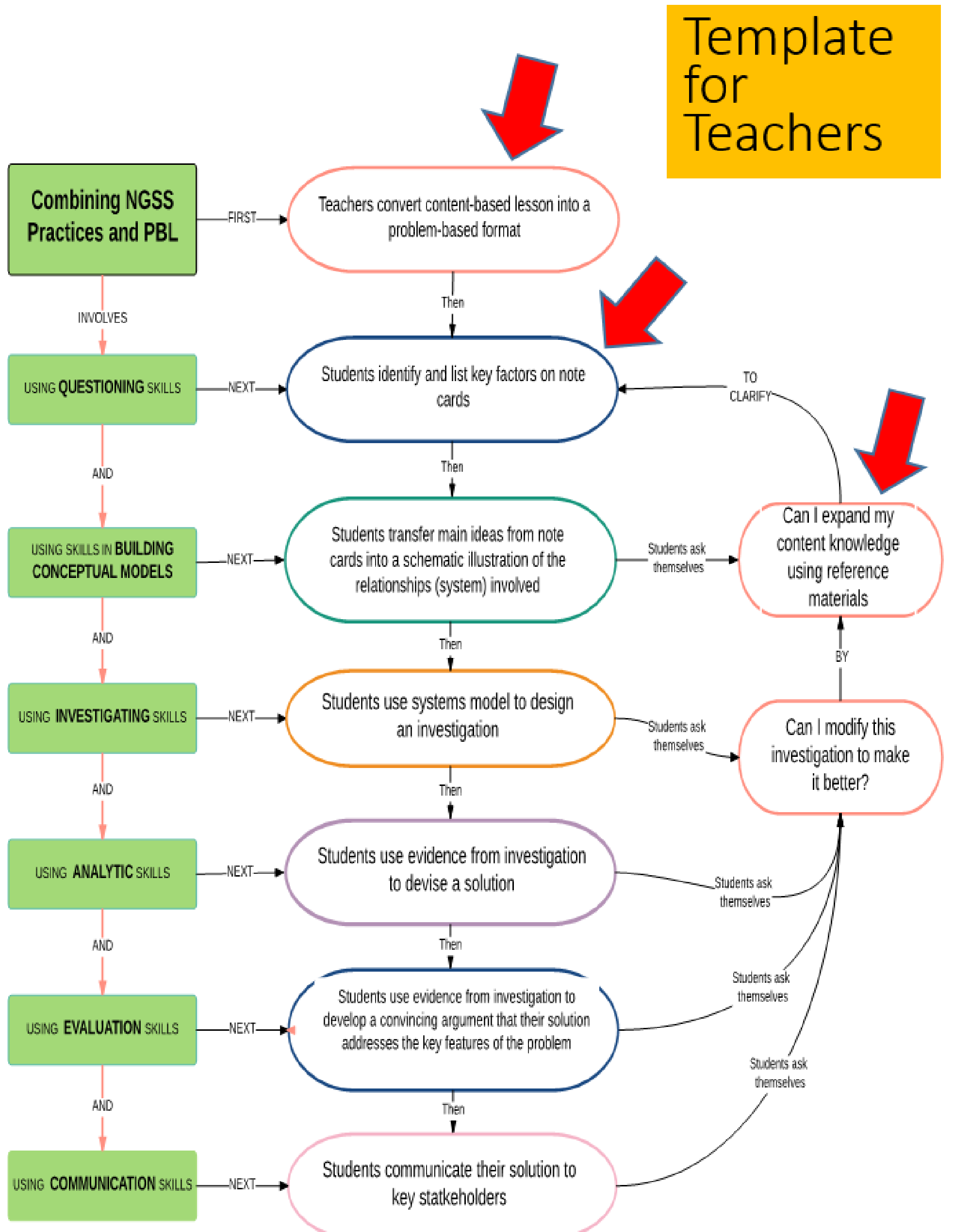
An example of efficiency and routine expert: [The Expert Witness](http://www.nytimes.com/video/opinion/100000004115589/verbatim-expert-witness.html?em_pos=medium&emc=edit_fs_20151231&nl=video&nlid=25051222) http://www.nytimes.com/video/opinion/100000004115589/verbatim-expert-witness.html?em_pos=medium&emc=edit_fs_20151231&nl=video&nlid=25051222

Efficiency and exploration are two components of any workplace experience. Efficiency is the effort to focus on the immediate task or goal, while exploration is the desire to try new things.

Too much exploration can lead to a frustrated employee, while too much efficiency can lead to a routine expert.

When the two are balanced, employees learn a variety of tasks and achieve optimal learning, becoming adaptive experts.

Helping frame content into systems thinking



1. Teachers combine next generation science standards practices by converting content-based lessons into a problem-based format.

2. This involves using questioning skills to help students identify and list key factors on note cards.

3. Students use conceptual model building skills to transfer main ideas from note cards into a schematic illustration of the relationships and systems involved. Students ask themselves "Can I expand my content knowledge using reference materials?" If yes, students return to step 2.

4. If no, students use investigative skills and systems models to design an investigation. Students ask "Can I modify this investigation to make it better?" If yes, return to step 3.

5. If no, students use analytical skills, in conjunction with evidence from the investigation to devise a solution. Students continue to ask "Can I modify this investigation to make it better?" If the answer is yes they return to an earlier step.

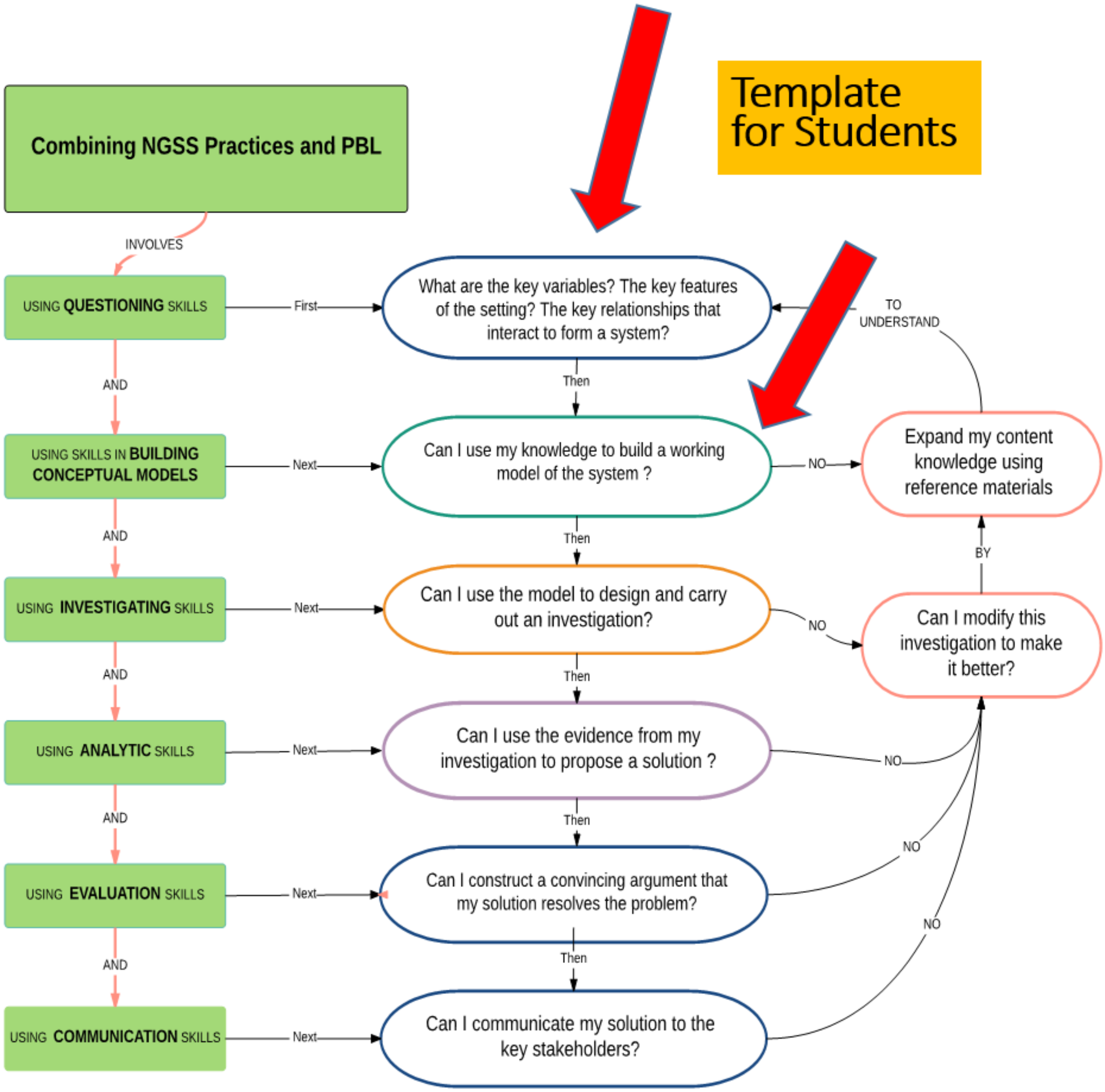
6. Using evaluation skills, students will use evidence from their investigation to develop a convincing argument that their solution address the key features of the problem. Students will continue to ask if they can improve their investigation.

7. Using communication skills, students communicate their solution to key stakeholders. If they do not believe they can improve their investigation then the task is complete.

- Select a unit of instruction
  - Example: Weather, Nutrition, Solar System
- Reframe the unit as a problem (question) students will address
  - Examples: How would you improve on-time delivery? What lean concepts can be applied to improve efficiency and productivity? How can we reduce scrap?
- Write the key content topics on note cards
  - Examples: Considering the amount of time for preproduction work vs production. Shop cleanliness and organization of tools, improving programing and set up
- Convert the note cards into a systems map that depicts how the topics interact
  - Examples: map out production process from receipt of order to shipping and time for each step, map out an improved organization of tools, map out the set up process and first piece inspections at each operation
- Consider how to use the system map as a guide for instruction

What resources can you provide for students? How will you balance efficiency with exploration?

Helping students understand systems thinking



1. In order to combine next generation science standards and problem-based learning, students will use questioning skills to determine "What are the key variables? The key features of the setting? The key relationships that interact to form a system?"

2. Using concept model building skills, students determine "Can I use my knowledge to build a working model of the system?" If not, students will expand their content knowledge using reference materials, in order to better understand the questions in step 1.

3. Using investigative skills, students will determine "Can I use the model to design and carry out an investigation?" If not, "Can I modify this investigation to make it better", returning to an earlier step.

4. Using analytical skills, students will determine "Can I use evidence from my investigation to propose a solution?" If not, return to an earlier step.

5. Using communication skills, students will determine "Can I communicate my solution to the key stakeholders?" If not, return to an earlier step.

- Select an experience familiar to students
  - Example: A sports game they won or lost
- Ask students to write on note cards all of the factors that were key variables in that activity
  - Examples: Injuries to players, referee, crowd influence, intangible factors
- Ask students to group the cards into key themes
  - Examples: Game conditions, Motivational factors, Skill levels, Intangibles
- Ask students to craft a systems map showing how the key interactions influenced the outcome
  - Examples: Injuries to players reduced a teams' skill advantage; Referee's perspective gave an advantage to one team, Crowd provided and incentive to home team
- Discuss with students how the interactions (systemic map) provides a framework for analyzing the game

Activity with Students

Identify the total manufacturing process from beginning to end:

Sale through Delivery

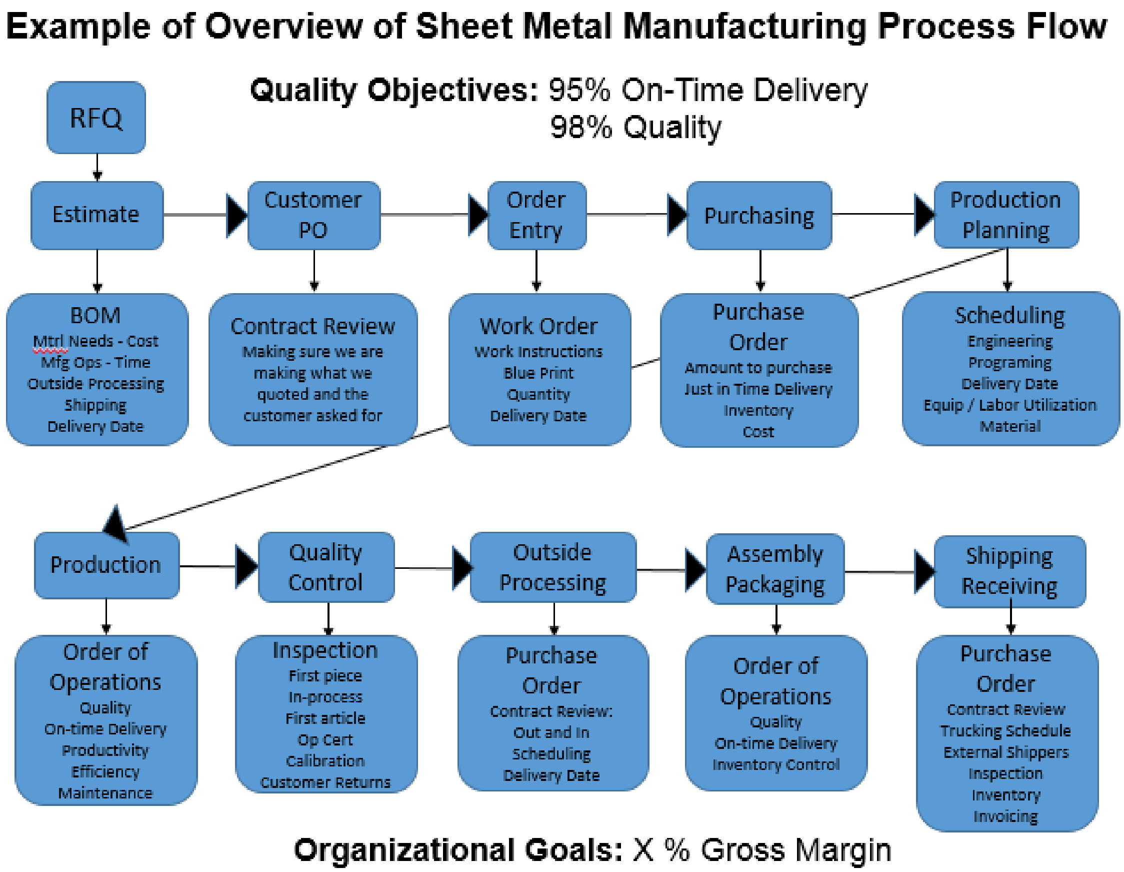
Identify what can go wrong where.

How do you know that is the correct cause of the problem?

How do you fix problems that occur?

How do you ensure the problem is corrected?

Example Overview of Sheet Metal Manufacturing Process Flow



1. An RFQ (Request For a Quote) leads to an estimate, which includes a BOM (Bill of materials), documenting the material needs, the time to complete the work, any outside processes, shipping expenses and an estimated delivery date.

2. A Customer PO (Purchase Order), outlines the contract, to ensure that the customer and manufacturer are in agreement.

3. Order Entry or work order provides instructions, blueprints, quantities, and delivery dates to the manufacturing employees.

4. A Purchase Order confirms the types and quantities of raw materials to be purchased, time of delivery, and cost.

5. A Production Plan outlines the engineering and programming work necessary, the equipment and labor to accomplish said tasks, necessary materials, and delivery date.

6. Production begins, using a clear Order of Operations outline to establish the necessary quality, completion dates, and any maintenance that may be necessary along the way.

7. Quality Control is maintained through inspections during the process.

8. Outside Processing reviews the purchase order, ensuring that everything is on schedule.

9. Assembly Packaging prepares the deliverables for shipment, and ensures that delivery will be on time.

10. Shipping Receiving review the contract, confirm that all deliverables have been met, and arrange for transport and delivery.

Systems Thinking Resources

Systems Thinking by Senge:

https://www.solonline.org/?page=SystemsThinking

The Systems of Profound Knowledge

https://deming.org/theman/theories/profoundknowledge

A video of Peter Senge explaining the fundamental rational of systems thinking and how to give perspectives on problems to have leverage and insight on decision making.

(http://www.mutualresponsibility.org/science/what-is-systems-thinking-peter-senge-explains-systems-thinking-approach-and-principles)

One philosophy of 14 points that can be applied to any organization to thrive

(https://leanandkanban.wordpress.com/2011/07/15/demings-14-points/)

Peter Senge and the learning organization

http://infed.org/mobi/peter-senge-and-the-learning-organization/

W. Edwards Demming: The 14 Points

https://www.youtube.com/watch?v=tsF-8u-V4j4

The similarities of strategic thinking and systems thinking.

(https://backwardstimemachine.wordpress.com/2013/01/08/strategic-thinking-and-systems-thinking/)

The development of organic organizations to foster learning and continuous improvement in order to attain student achievement.

(http://donnaelder.wiki.westga.edu/file/view/Systems+Thinking+A+skill+to+Improve+Student+Achievement.pdf)

Intertwining language and thinking skills to develop Systems Thinking.

(http://www.fi.muni.cz/~xpelanek/IV109/jaro07/IST.pdf)

Learning Organizations:

How systems thinking can transform organizations to learning organizations.

(http://www.spe.org/twa/print/archives/2007/2007v3n3/twa2007_v3n3_Soft_Skills.pdf)

5 questions that lead to systems thinking.

(http://www.akrna.com/why-our-mission-advocates-systems-thinking/)

Unit 2a: Problem Solving: Developing Curriculum Around Problem Statements

Problem Statements:

What are the characteristic of good problem-solving skills?

What are the learning outcomes (i.e. competencies, skill set) of a good problem based learner that is able to solve novel real world problems?

How do these learning outcomes match industry needs?

How do I develop good problem-based learners ability to solve real world problems that will meet industry demand for good workers?

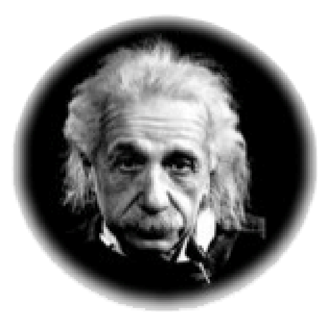
Objective: To incorporate principals that will support the development of student problem solving skills into course curriculum and teaching practices.

What are the characteristics of good problem solving skills?

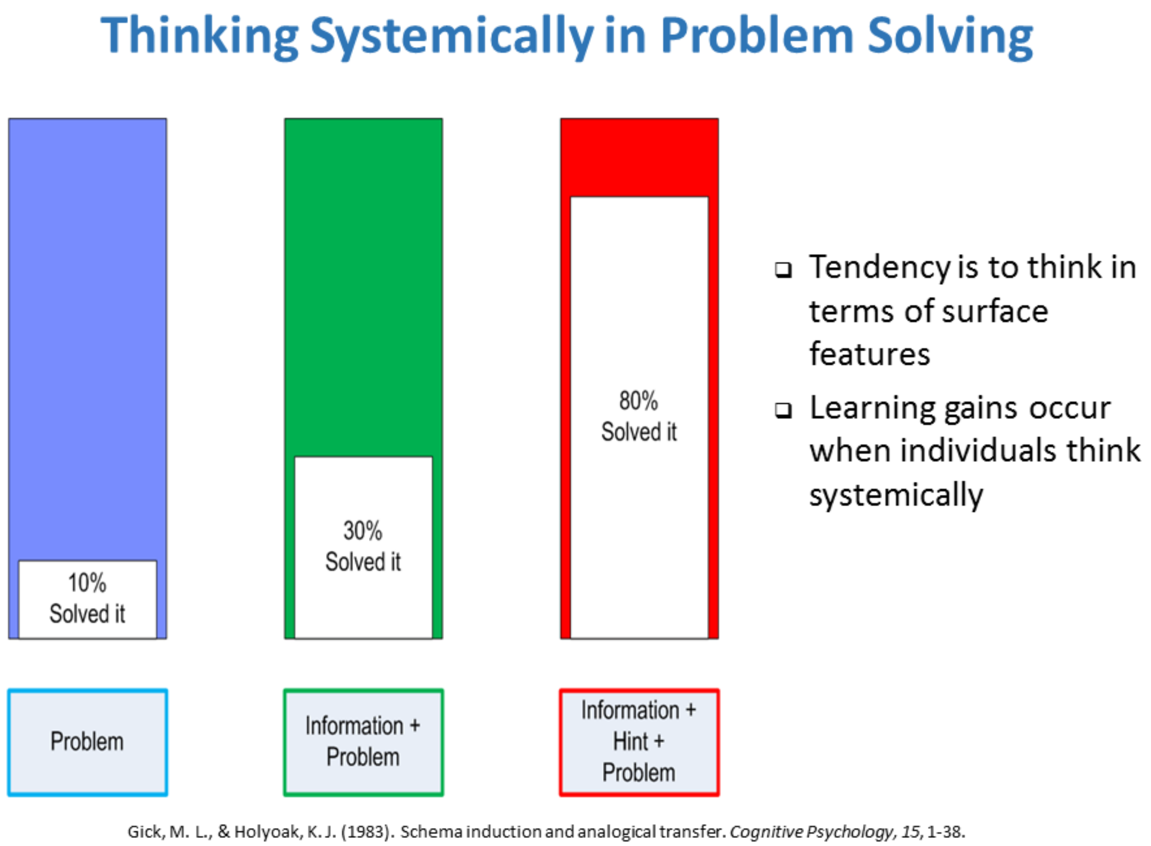
- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using computational thinking
- Constructing explanations and solutions
- Engaging in argument from evidence
- Evaluating and communicating information

“We cannot solve our problems with the same thinking we used when we created them.”

-Albert Einstein



Thinking Systemically in Problem Solving



Understanding the problem is 10% of the solution. With additional information the student achieves 30% of the solution. With an understanding of the problem, additional information, and a hint, the student can achieve 80% of the solution.

There is a tendency think in terms of surface features.

Learning gains occur when individuals think systemically.

Problem Solving as Transfer of Learning "out:"
Viewing learning as students' applying information to a new situation

RESEARCH QUESTION: How well had students' general education prepared them to address a novel problem?

METHOD:

- 5th graders and college students created a recovery plan to protect Bald Eagles from extinction
  - None of the participants had studied Eagle recovery plans explicitly

RESULTS

- Fifth Graders vs College students:
  - College Students writing and spelling skills superior to 5th Graders
- Neither group generated a recovery plan that was even close to being adequate.
  - No plans to counteract baby eagles imprinting on humans who fed them
  - No plans for towers so baby eagles would imprint on the area they would eventually call home

CONCLUSION

- General education did not prepare students to solve a novel problem

Discussion points on transfer of learning

- **In many classrooms students may respond to their read (perception) of the classroom environment as they experience it**

  -My role is to come to class, not misbehave, pay attention, complete assignments as directed

- **Because students often identify problem-based "activities" (e.g., math games, projects) and "group work" as instances where they often felt like good learners, these situations might be expanded and refined**

  -Converting lesson plans into problem scenarios would provide students with more options to develop skills as good problem-based learners

- **If considerations of shifting students' learning towards good problem based learners are pursued, these considerations may necessarily include explorations of ways to refine the classroom environment**

  -A classroom that focused on problems – not presentations – would accelerate students' development as problem-based learners

Perspective

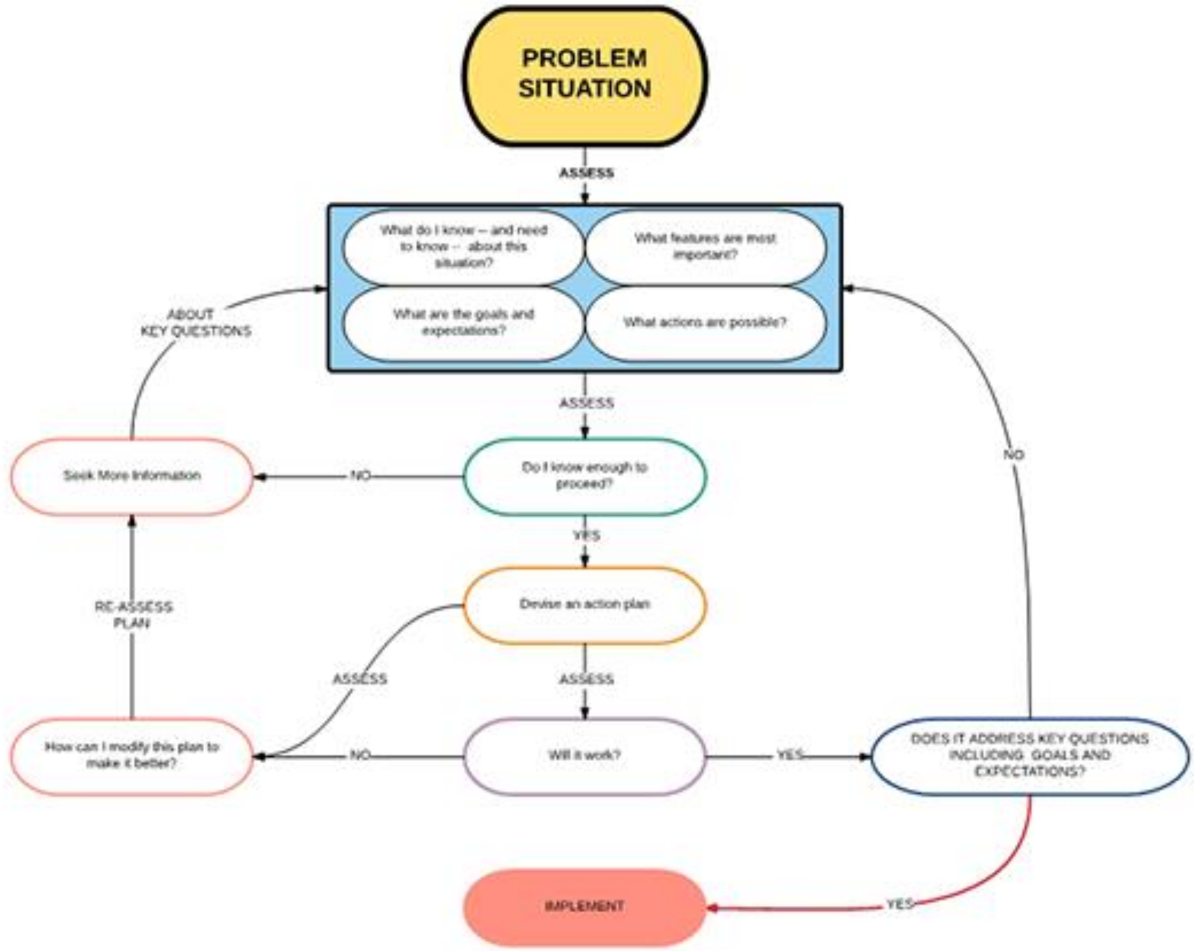
What's wrong with an educational system where college students perform no better than 5th graders when faced with a novel problem?

Consider Father Guido Sarducci's perspective

https://www.youtube.com/watch?v=c00GPvns31U

Problem Solving Template

The problem solving process is not at all linear or step-by-step. It's a recursive process.



1. Assess the problem situation.

- What do I know -- and need to know -- about this situation?
- What features are most important?
- What are the goals and expectations?
- What actions are possible?

2. Assess the information. Ask "Do I know enough to proceed.

If the answer is no, seek out more information using the questions from step 1.

3. If the answer is yes, devise an action plan.

Assess the action plan. Ask "Will it work?"

4A. If no, ask "How can I modify this plan to make it better?" Seek out more information and return to step 1.

4B. If yes, ask "Does this address key questions including goals and expectations.

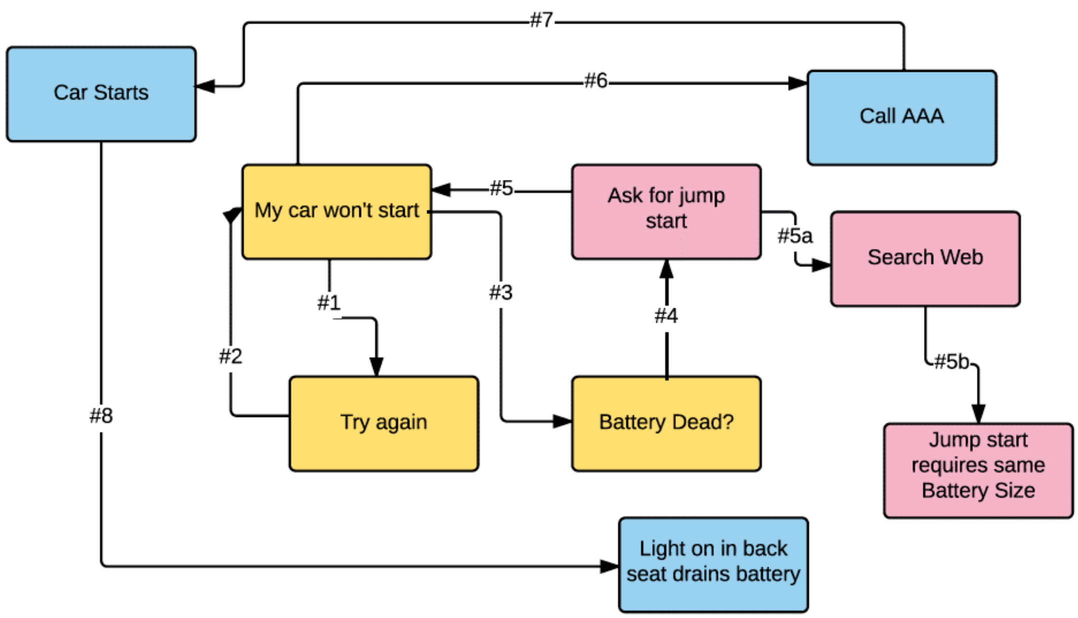
If no, return to step 1.

If yes, implement the plan.

Problem-Based Learning Process

- Think of a time when you solved a problem--and learned from the process.
- Describe and map out the steps you took.

For example



1. My car won't start.

2. Try again.

3. My car still won't start.

4. Is the battery dead?

5. Ask for a jump start.

6A. Search the Web

6B. Learn that a jump start requires the same Battery Size.

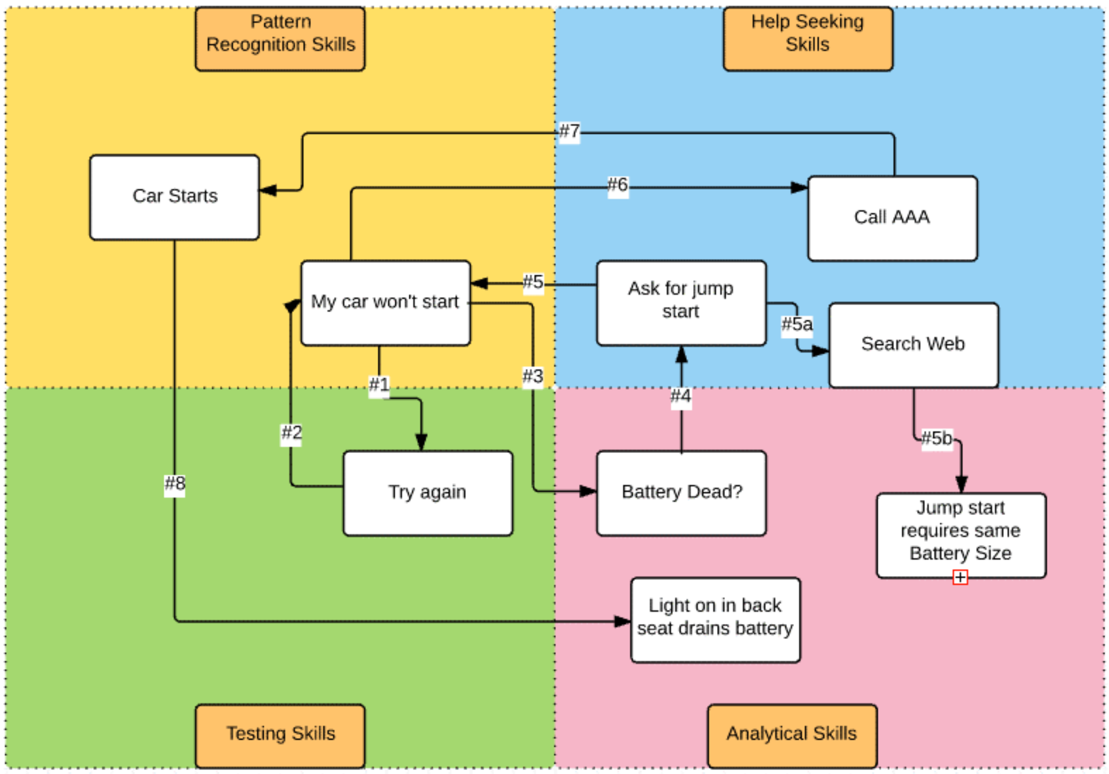
7. Call AAA

8. Car Starts

9. Learn that a light on in the back seat drained the battery.

Problem-Based Learning Skills

- Describe the skills you used that helped you learn.
- Try to clarify and group the skills.



1. My car won't start. (Pattern Recognition Skills)

2. Try again. (Testing Skills)

3. My car still won't start. (Pattern Recognition Skills)

4. Is the battery dead? (Analytical Skills)

5. Ask for a jump start. (Help Seeking Skills)

6A. Search the Web. (Help Seeking Skills)

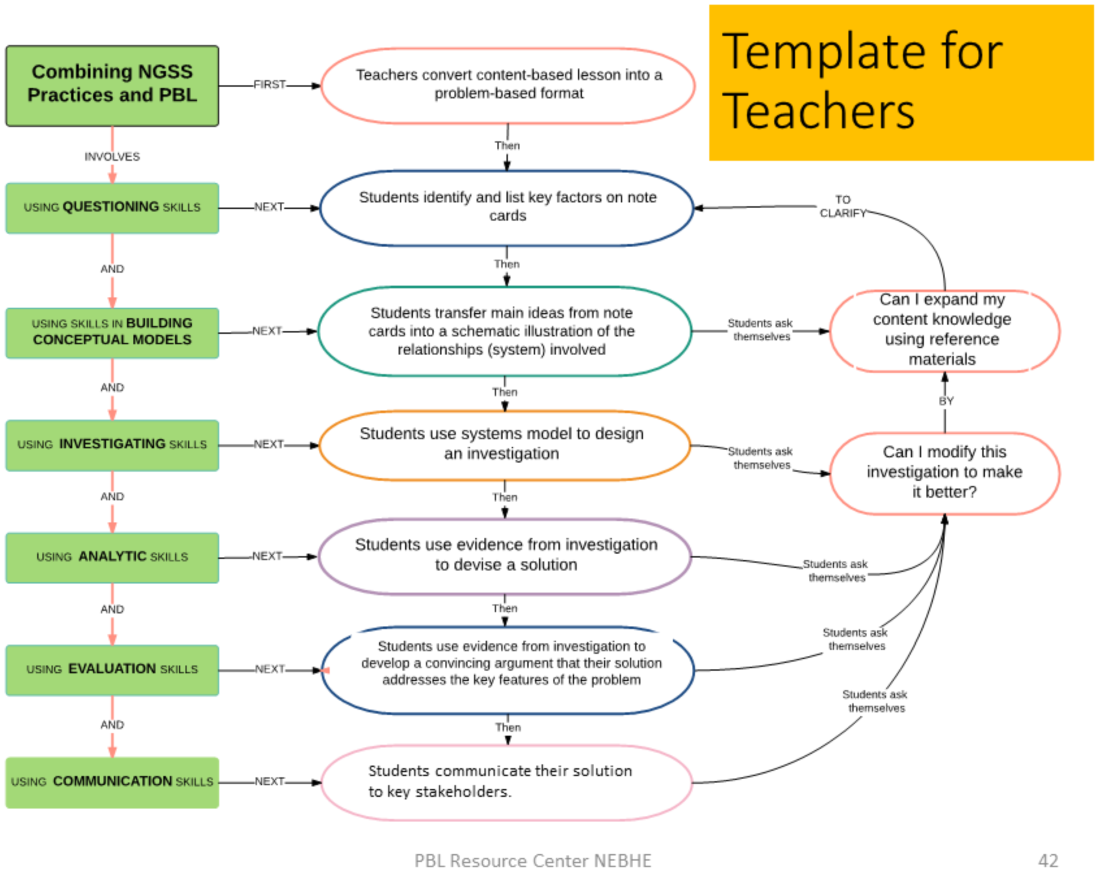
6B. Learn that a jump start requires the same Battery Size. (Analytical Skills)

7. Call AAA (Help Seeking Skills)

8. Car Starts (Pattern Recognition Skills)

9. Learn that a light on in the back seat drained the battery. (Analytical Skills)

Template for Teachers



1. When combining next generation science standards with problem based learning, instructors need to convert content-based lessons into a problem based format.

2. Using questioning skills, students identify and list key factors on note cards.

3. Using conceptual modeling skills, students transfer main ideas from note cards into a schematic illustration of the relationships, and systems involved. Students ask themselves "Can I expand my content knowledge using reference materials to clarify the key factors?" If the answer is yes they return to step 2. If not, they continue on.

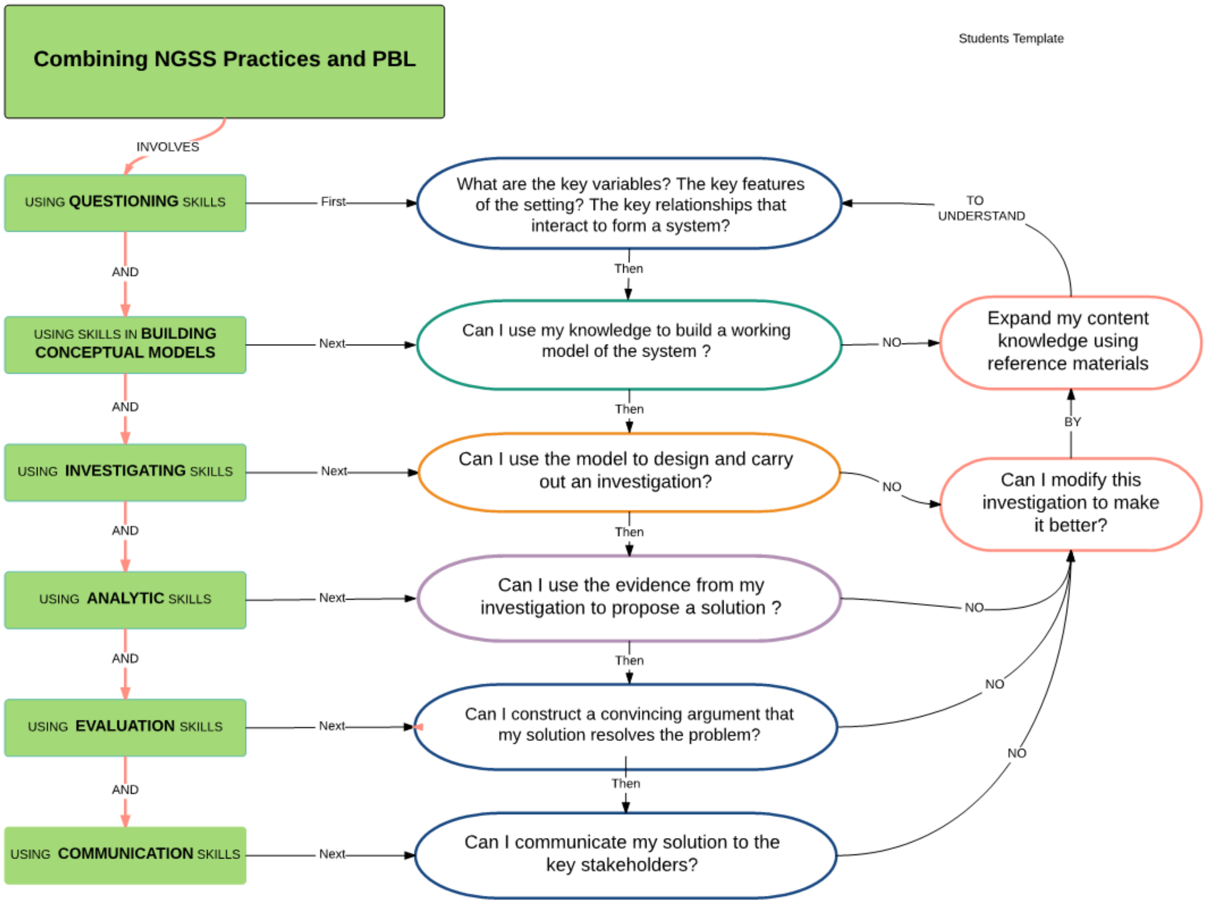
4. Using investigative skills, students use systems model to design an investigation. Students ask themselves "Can I modify this investigation to make it better by expanding my content knowledge using reference materials?" If the answer is yes, the student will return to an earlier step to refine their process. If not, they continue on to the next step.

5. Using analytic skills, students use evidence from investigation to devise a solution. Students continue to ask themselves if their investigation can be improved, and if the answer is yes, they return to a prior step. If not, they continue on.

6. Using evaluation skills, students use evidence from the investigation to develop a convincing argument that their solution addresses the key features of the problem. Students continue to ask themselves if they can improve upon their process through additional reference materials. If the answer is yes, they return to an earlier step. If not, they continue.

7. Using communications skills, students communicate their solution to key stakeholders. Students continue to ask themselves if they can improve upon their process through additional reference materials. If the answer is yes, they return to an earlier step. If not, they are finished.

Template for Students



1. When using a system that combines next generation science standards with problem based learning, students begin by using questioning skills to ask "What are the key variables. The key features of the setting? The key relationships that interact to form a system?"

2. Students use conceptual modeling skills to ask "Can I use my knowledge to build a working model of the system?" If the answer is no then they expand their existing knowledge using reference materials to better understand the questions asked in step 1.

3. If the answer is yes, students use investigative skills to ask "Can I use the model to design and carry out an investigation?" If the answer is no the student modifies their investigation to improve upon it, using reference materials to expand their content knowledge, and better understand the questions asked in step 1.

4. If the answer is yes, students use analytical skills to ask "Can I use the evidence from my investigation to propose a solution?" If the answer is no students will return to an earlier step and modify their investigation.

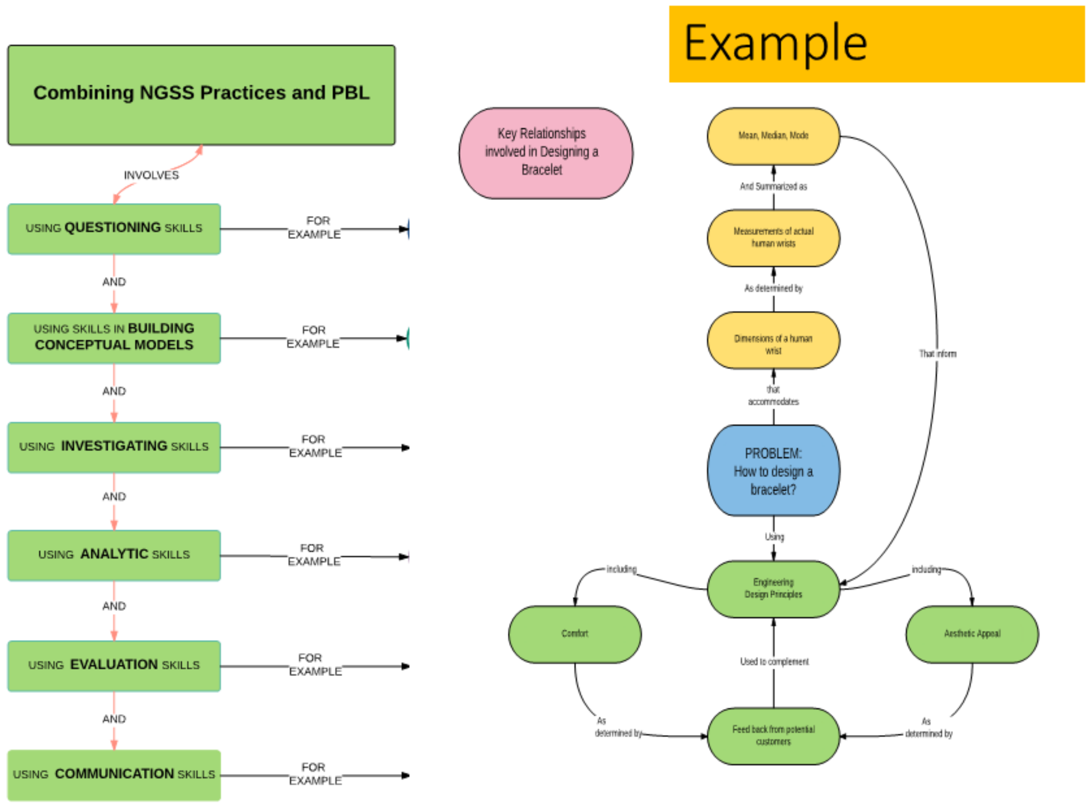
5. If the answer is yes, students use evaluation skills to ask "Can I construct a convincing argument that my solution resolves the problem?" If the answer is no students will return to an earlier step and modify their investigation.

6. If the answer is yes, students use communications skills to ask "Can I communicate my solution to the key stakeholders?" If the answer is no students will return to an earlier step and modify their investigation. If the answer is yes the task is complete.

Using the Template for Teachers

- Re-frame a content-based lesson into a problem-based lesson.
  Design a schematic that represents your view of the key relationships involved in the problem.
  - Pose a problem (question) for students to resolve.
- Design a schematic that represents your view of the key relationships involved in the problem.
- Consider the key relationships students might investigate in addressing the problem.
- Consider the types of evidence students might collect.
- Consider how students might evaluate the evidence to propose and support a solution.
- Consider the ways students might communicate their solution to key stakeholders.

Example



1. In this example the initial problem is defined as "How to design a bracelet?"

2. The problem is further defined by requirements:

- Bracelet must accommodate the dimensions of a human wrist, as determined by measurements of actual human wrists, which are summarized as the mean, median, and mode of the statistical data.

3. This research informs the engineering design principles, which include comfort, aesthetic appeal, and feedback from potential customers, which also inform the engineering design principles of the bracelet.

Other Resources for Problem Solving

There are many different documented problem solving processes. Several are recognized and used in the manufacturing industry, such as root cause analysis and the 5 Whys. All of the process have value and are useful. The thing to remember is that problem solving is a recursive process, not a linear process. Although each of the following problem solving processes depict a step-by-step process, each step can be gone back to and repeated many times.

New England Board of Higher Education White Boards

Step 1. Problem Analysis

The first step in problem solving is to clearly define the problem. Exactly what is the problem you are trying to solve and what is the desired outcome? To do this, you must first identify and list the criteria against which your solution will be measured. You must identify what you know about the problem (i.e., what is given) and any assumptions you need to make if information is missing. Once you have clearly defined the problem, you are ready to move forward and seek out the knowledge and skills needed to solve the problem.

Clearly define the problems:		
What are the criteria for a successful solution?	What do we know about the problem?	Are there any assumptions we must make?

What is root cause analysis?

Root Cause Analysis (RCA) is a popular and often-used technique that helps people answer the question of why the problem occurred in the first place. It seeks to identify the origin of a problem using a specific set of steps, with associated tools, to find the primary cause of the problem, so that you can:

1. Determine what happened.
2. Determine why it happened.
3. Figure out what to do to reduce the likelihood that it will happen again.

RCA assumes that systems and events are interrelated. An action in one area triggers an action in another, and another, and so on. By tracing back these actions, you can discover where the problem started and how it grew into the symptom you're now facing.

You'll usually find three basic types of causes:

1. **Physical causes** – Tangible, material items failed in some way (for example, a car's brakes stopped working).
2. **Human causes** – People did something wrong, or did not do something that was needed. Human causes typically lead to physical causes (for example, no one filled the brake fluid, which led to the brakes failing).
3. **Organizational causes** – A system, process, or policy that people use to make decisions or do their work is faulty (for example, no one person was responsible for vehicle maintenance, and everyone assumed someone else had filled the brake fluid).

RCA looks at all three types of causes. It involves investigating the patterns of negative effects, finding hidden flaws in the system, and discovering specific actions that contributed to the problem. This often means that RCA reveals more than one root cause.

You can apply RCA to almost any situation.

Root Cause Analysis Process

The Root Cause Analysis Process
RCA has five identifiable steps.

Step One: Define the Problem
What do you see happening?

What are the specific symptoms?

Step Two: Collect Data
What proof do you have that the problem exists?

How long has the problem existed?

What is the impact of the problem?

You need to analyze a situation fully before you can move on to look at factors that contributed to the problem. To maximize the effectiveness of your RCA, get together everyone – experts and front line staff – who understands the situation. People who are most familiar with the problem can help lead you to a better understanding of the issues.

Step Three: Identify Possible Causal Factors:
What sequence of events leads to the problem?

What conditions allow the problem to occur?

What other problems surround the occurrence of the central problem?

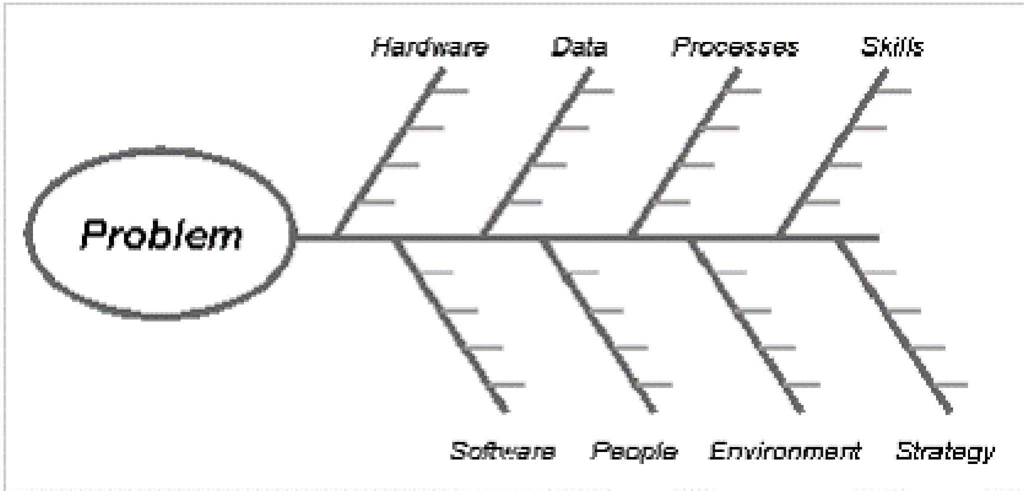
During this stage, identify as many causal factors as possible. Too often, people identify one or two factors and then stop, but that's not sufficient. With RCA, you don't want to simply treat the most obvious causes – you want to dig deeper.

Ask the 5 WHYS
This is a technique where the student asks "why" five times, to get past the surface answers.

Step Four: Identify the Root Cause(s)

- Why does the causal factor exist?
- What is the real reason the problem occurred?

Use the same tools you used to identify the causal factors (in Step Three) to look at the roots of each factor. These tools are designed to encourage you to dig deeper at each level of cause and effect.



A problem is a combination of various variables, including hardware, software, data, people, processes, environments, skills, and strategies.

Step Five: Recommend and Implement Solutions
What can you do to prevent the problem from happening again?

How will the solution be implemented?

Who will be responsible for it?

What are the risks of implementing the solution?

Analyze your cause-and-effect process, and identify the changes needed for various systems. It's also important that you plan ahead to predict the effects of your solution. This way, you can spot potential failures before they happen.

Summary

- PBL activities increase performance of all students – especially students with lower levels of achievement.
- Across all levels, capacity for systemic thinking is the most robust outcome of education.
- Optimal path for developing adaptive expertise balances efficiency (getting right answer) with exploration (seeking innovation).
- Teachers can build a curriculum that enhances systemic thinking by using series of problem based modules.

Suggestions for Moving Forward

- Introduce good student -- good learner continuum
- Introduce self-regulations and deep practice
- Invite students to reflect on learning each week
- Introduce problem solving template
- Invite students to use it as a guide
- Design overarching question
- Consider a question that helps students link discrete activities with cross-cutting questions
- Integrate NEBHE challenges into lessons
- PBL Projects-Challenges (http://www.pblprojects.org/challenges-nebhe/)

Problem Solving Resources

Survey of Connecticut Manufacturing Workforce Needs

http://www5.cbia.com/newsroom/wp-content/uploads/2014/05/MFG-Workforce_14.pdf?_cldee=YnVkZGpAY2JpYS5jb20%3d&utm_source=ClickDimensions&utm_medium=email&utm_campaign=CD_NEWSROOM

Why problem solving is fundamental in your career

https://www.mindtools.com/pages/article/newTMC_00.htm

How innovation and efficiency effect collaboration and transferability of learning

http://iase-web.org/documents/dissertations/06.Sears.pdf

Stages of problem solving

http://www.skillsyouneed.com/ips/problem-solving.html

How to develop and demonstrate your problem-solving skills

https://www.kent.ac.uk/careers/sk/problem-solving-skills.htm

How to create learning environments that go beyond traditional assessment tests to real-life learning that leads students to be able to make good decisions independently

https://aaalab.stanford.edu/papers/Innovation%20in%20Transfer.pdf

How using analogy and analogical transfer can illustrate problems and solutions

https://deepblue.lib.umich.edu/bitstream/handle/2027.42/25331/0000776.pdf;jsessionid=EE4AA64EC41326D0D9896DED32544C23?sequence=1