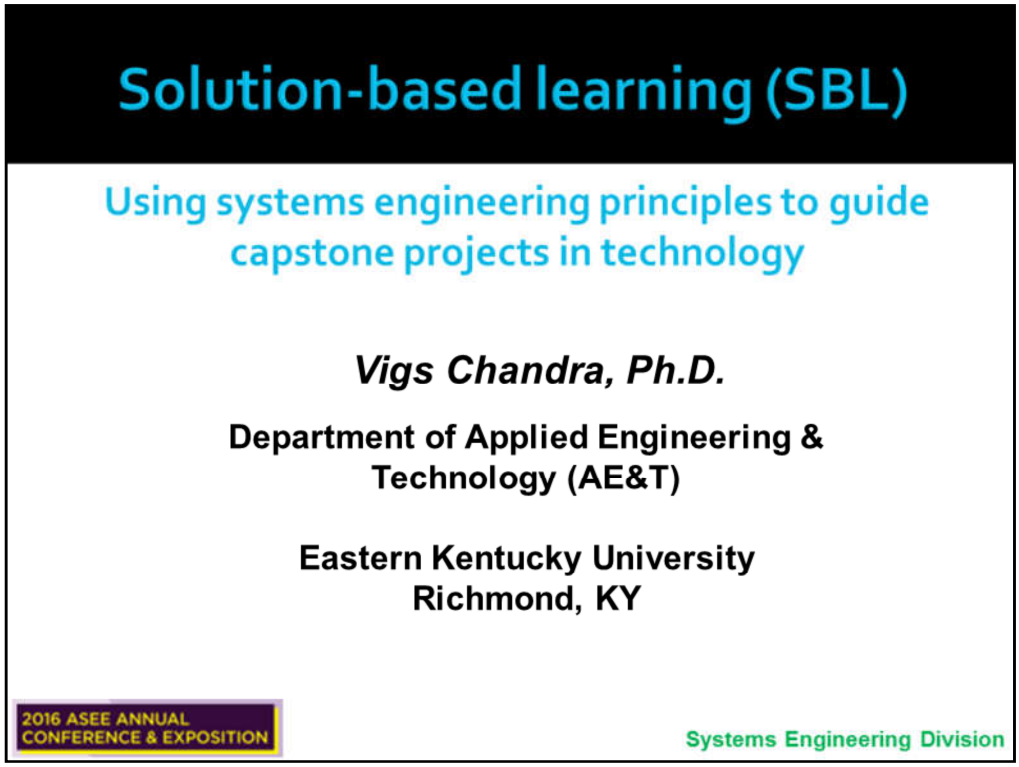
SBL is **borne out a deeply felt** need to give students a way to be successful right from the start of a long term project requiring the creation of a useful product they conceptualize, research, design, prototype, test/troubleshoot, improve, and demo.

And it is more than just about a product – as important as that it is – SBL provides the blueprint of a process that builds on the effort put into each stage, right from the inception to the completion of a project.

SBL may be visualized as an ever enlarging spiral of solutions is designed and deployed. The spiral includes new cases, more users, broader scope generalized beyond specific solutions, including entire systems and beyond. In learning which is solution based, the focus is on successively expanding the scope of solutions for a given system, situation, or scenario.

The approach being used is presented here.



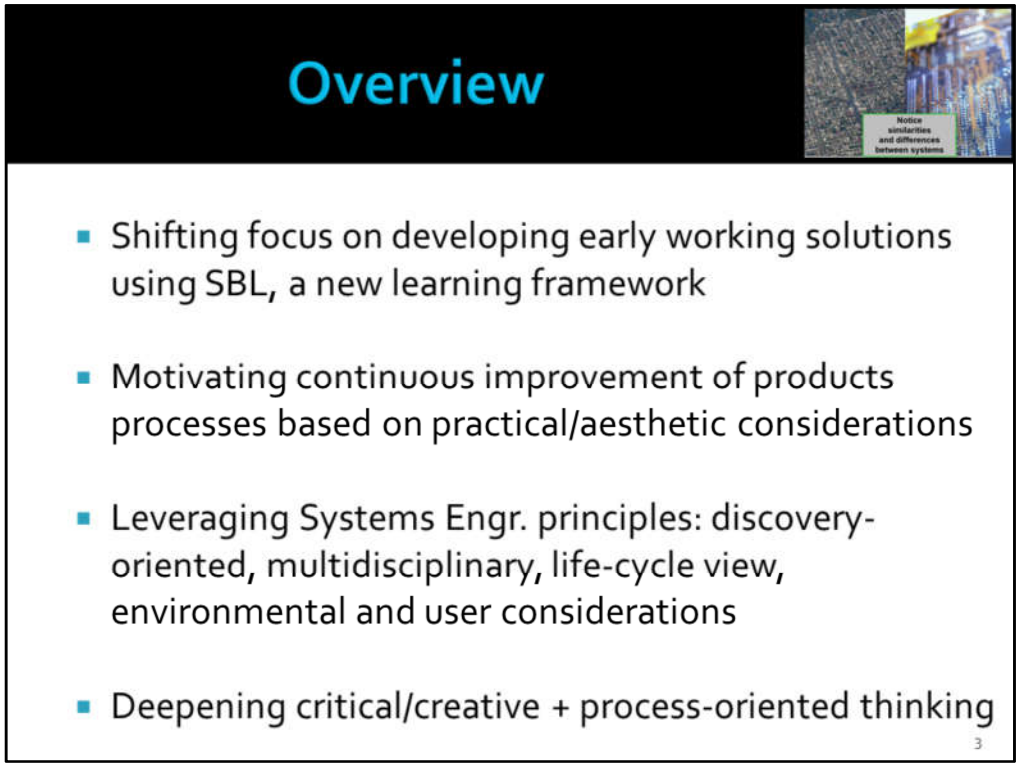
An **iterative process fundamentally explorative and expansive in its outlook**.

It seeks to build on the successes or solutions available or developed in each phase, continually improving various facets of a system including its operations, features, functionality, or form. Instead of looking only at shortcomings also focuses on successes – what went well (retain that in future iterations); what didn't (troubleshoot/fix/simplify/research/prototype)

SBL being used in the Network Security & Electronics (NET) program capstone course, a program accredited through ATMAE, the Association of Technology, Management, and Applied Engineering (ATMAE). Primarily a tech program. Our graduates are primarily employed as computer/network techs supporting IT, including electronic systems ops in school systems, hospitals, banks. They're the tech person everyone calls on in the organization. The program gives students a bit of all things computer tech related and is broad in scope. While the capstone in our program has teaming elements, it is primarily an individual effort. In this our program capstone is a bit different from the conventional ABET ones which are almost exclusively team based. We'll get into the details of this in a little bit later on in the presentation. I've been thinking about this process, have consulted and collaborated with faculty colleagues, particularly Prof. Jeff Kilgore and Dr. Ray Richardson; and our industrial advisory committee members at EKU for over a decade.

Particularly useful in design projects for practical systems – e.g., automation: pet feeder; or software: develop a database driven website for monitoring events; or integrated: Habitat ReStore relocation net cabling, security system, VoIP, computer imaging, cash registers, everything tech.

When students are tasked with a larger project, which they more often than note need to take from start to finish by themselves (as techies in small organizations/communities often need to) the SBL mindset can be helpful.



The **overriding requirement** in this type of learning is to develop practical solutions of the key sections early and often, and to refine and expand existing solutions with each successive iteration.

It encourages a positive outlook and continuous improvement focus while developing a practical project that serves an increasingly useful purpose for an ever expanding group of stakeholders.

SBL ties in with the interests and motivations of both the designer seeking to improve the system and of the existing/new users/stakeholders.

So why's this important in a capstone -- using SBL in the capstone allows students to focus their attention on solving a key part of their design, and to keep building on it. Focus on getting the main, the "meaty" part of the design, at least initially, instead of cosmetic features, that may require time as well. This can be helpful in providing a safety net they can return to (version control system), algorithmic thinking, the seeding subsequent stages, online research skills, building motivation to continue through rough patches.

Breath vs. Depth of content dilemma

Lecture (factual knowledge/thinking) vs. Laboratory (skills, attitudes, behavior) and projects

A mountain of technical content – projects provides a focus of the attention – linking otherwise disconnected topics within course or in the curriculum

Students grasp of a concept or particular skill needs to be strengthened after initial discussion and application.

Tech grad or firefighter!

Need ability to solve multifaceted, complex problems from day one

Quick leaners

Adapt existing solutions to new problems

Aggregating key information

Making things work together

Cutting costs

Researching information online

Evaluating competing product specifications

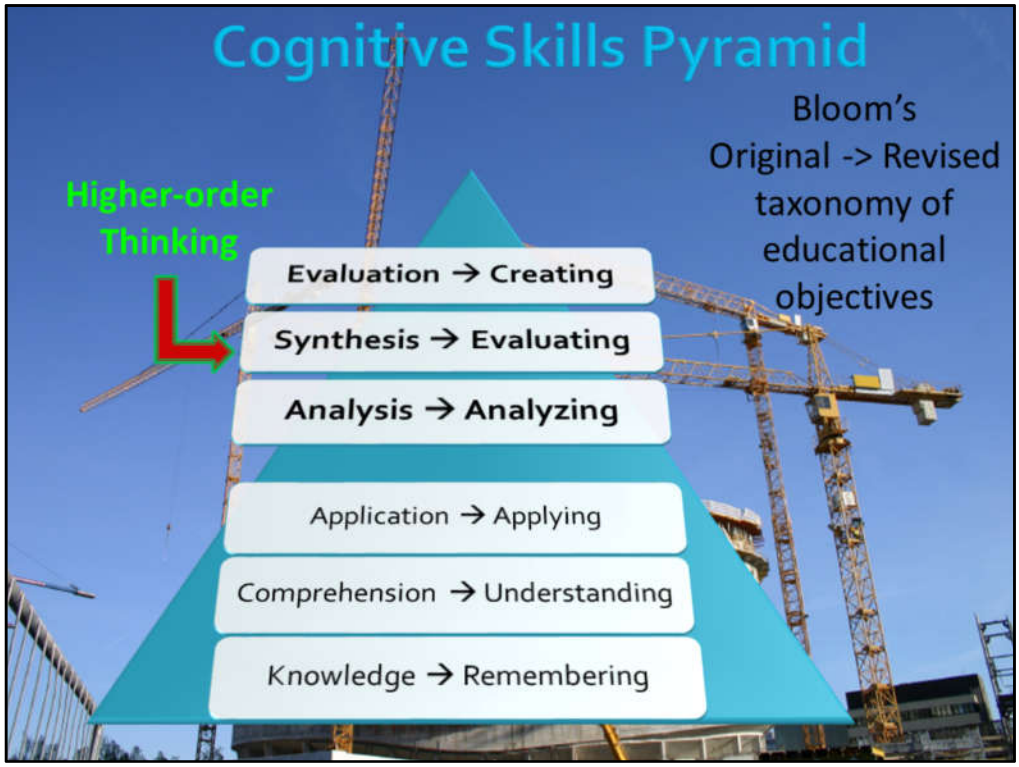
Creativity and teaming

People skills

Diverse workplace, local and global sensitivity

Ethics

Professional



Developing higher-order thinking skills in tech

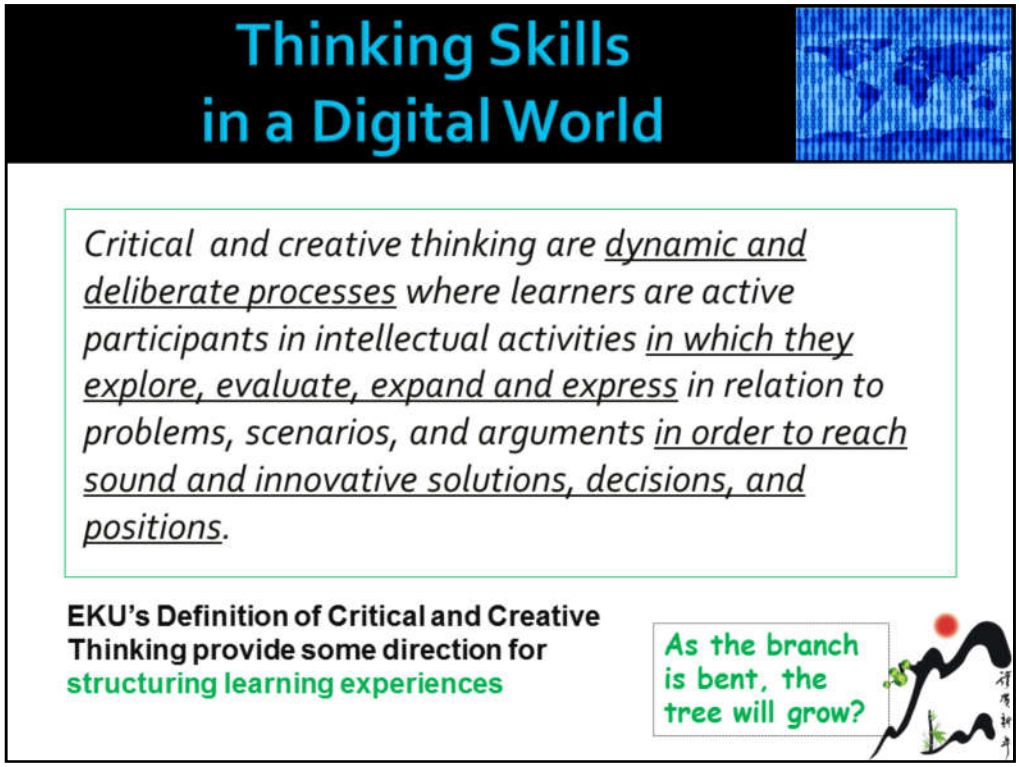
Troubleshooting scenarios – place student in role of consultant

Web-based activities: Online search strategies for identifying sources of valid information

Evaluating competing technology products

Class projects – preparation for developing larger NET applications

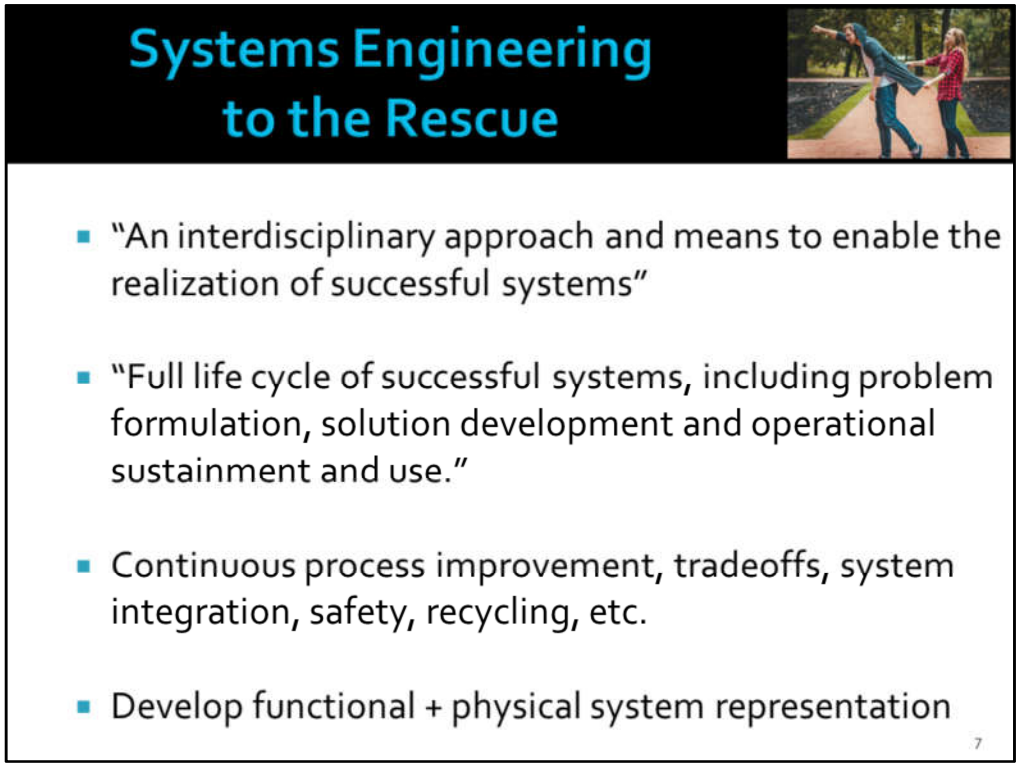
Program capstone course – all program courses are feeders into the final capstone experience



Knowledge-based organizations of the present and future require professionals to use these thinking skills.

US Bureau of Labor Statistics, which provides a comprehensive list of educational requirements for all occupations, ranks critical thinking among the top qualities by professionals in various disciplines. Hence, any training aimed at improving critical thinking and problem solving for students as part of their curriculum is also likely to improve opportunities for professional success in the future.

Techs and engineers as doers and thinkers.

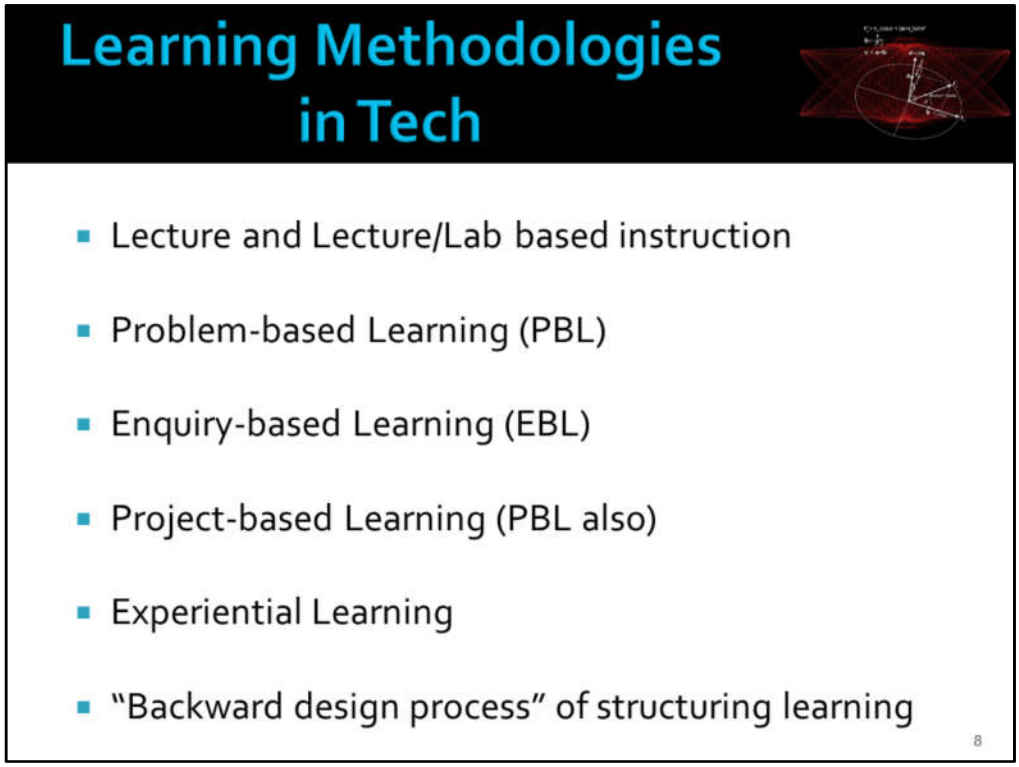


Capstone experience, a single 16 week course for students: the amount of development in thinking and doing is **a lot to ask of one course**, even of a series of courses. The systems engineering view can be very helpful here.

The International Council on Systems Engineering (INCOSE) defines Systems Engineering as "an interdisciplinary approach and means to enable the realization of successful systems."

The Systems Engineering Body of Knowledge (SEBoK), created by Body of Knowledge and Curriculum to Advance Systems Engineering (BKCASE) project, notes that systems engineering includes the "full life cycle of successful systems, including problem formulation, solution development and operational sustainment and use." As noted in the SEBoK, a host of criteria such as continuous process improvement, considerations for tradeoffs, system integration, safety, recycling, etc., are needed while developing solutions for technical problems.

Systems engineering process does not shy away from introducing the tradeoffs that are inevitable while designing, prototyping, and improving systems. These include improvements in safety, costs, security, efficiency, speed, size, quality, user experience, upgrade functionality, modularity, durability, redundancies, ease-of-maintenance, re-configurability, multi-use capabilities, recyclability, reduced variability, and considerations for legal and ethical issues.



Learning paradigms abound … and here's a proposal to add another to the mix. From the traditional lecture based formats we were initially trained with.

Problem-based learning (PBL) as defined by Barrows, includes a well formulated problem as the focus for stimulating student centered learning in small groups, using facilitators instead of teachers. It leads to the development of skills related to problem solving, stimulation of the cognitive process, and new knowledge as part of this process.

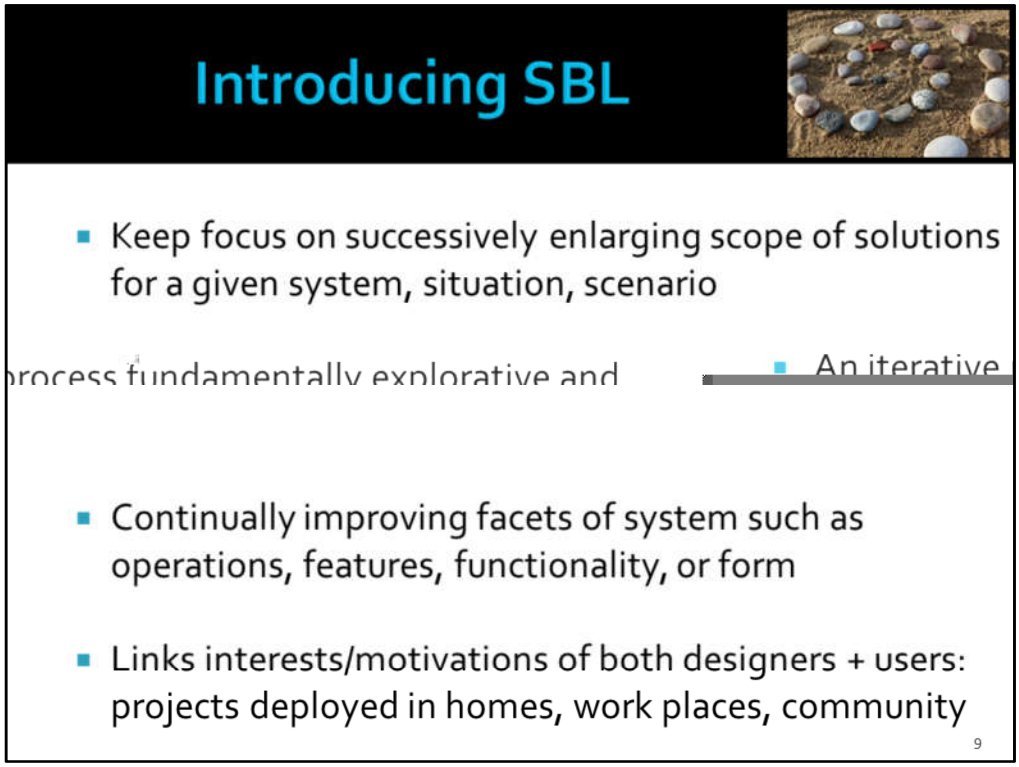
Problem BL viewed as a specialized type of open Inquiry-based or Enquiry-based learning (EBL) wherein the often rocky road to new knowledge is explored by investigating open questions, issues, scenarios, or problems; using models of thinking; researching ideas; designing experiments; performing observations; analyzing results; computing; using evidence; and providing explanations and communicating results

Project BL finding the solution of a problem resulting in an end product. Projects spanning a considerable amount of time. The learning activities are motivated by a problem at the root of the project.

Experiential aspects of learning, state that it "is not isolated from experience but grows out of experience," along with the idea that such, "Learning is not fragmented but holistic." Personal interest, the motivation to succeed on a self-defined set of technical goals, is quite different from that preselected for the student. This "reflection-in-action", as defined by Schön, develops out of one's experiences, a knowing in ones very actions while performing technical or professional work.

As part of actively engaging students in the learning process, the "backward design process" pioneered by Wiggings & McTighe may be used. It requires curriculum designers to first identify core competencies associated with the course and link evidence indicating its achievement. Course assessments and activities are designed for ensuring achievement of these competencies. In order to facilitate transfer of learning from the classroom to the workforce, Bransford, Brown, and Cocking[8] suggest that students initially be provided with opportunities for working on scaled-down versions of problems. These practical ideas can be used in the design of technology capstone projects.

Solution-based Learning (SBL)



Other learning paradigms provide an abundant learning space. SBL takes a different take on the issue. More than a semantic difference, a substantive one.

Right **from the git-go**, the overriding requirement in this type of learning is to develop solutions early and often, and to refine and expand existing solutions with each successive iteration. But not just starting anywhere, ID the core part of the project, sketch it out, talk about it, add to it conceptually first. Then …

Solution-based learning incorporates elements of problem- and project-based learning, enquiry-based and experiential learning. While it uses projects involving the creation of tangible products, the focus remains on the process of creating and improving solutions in all situations. It is multidisciplinary in nature and informed by advances in cognitive science. This solution-oriented mindset is intended to extend out of the classroom into the workforce where it can be used to develop effective solutions for tackling complex issues.

Encourages a positive outlook and continuous improvement

Develops a practical project that serves an increasingly useful purpose for an ever expanding group of stakeholders

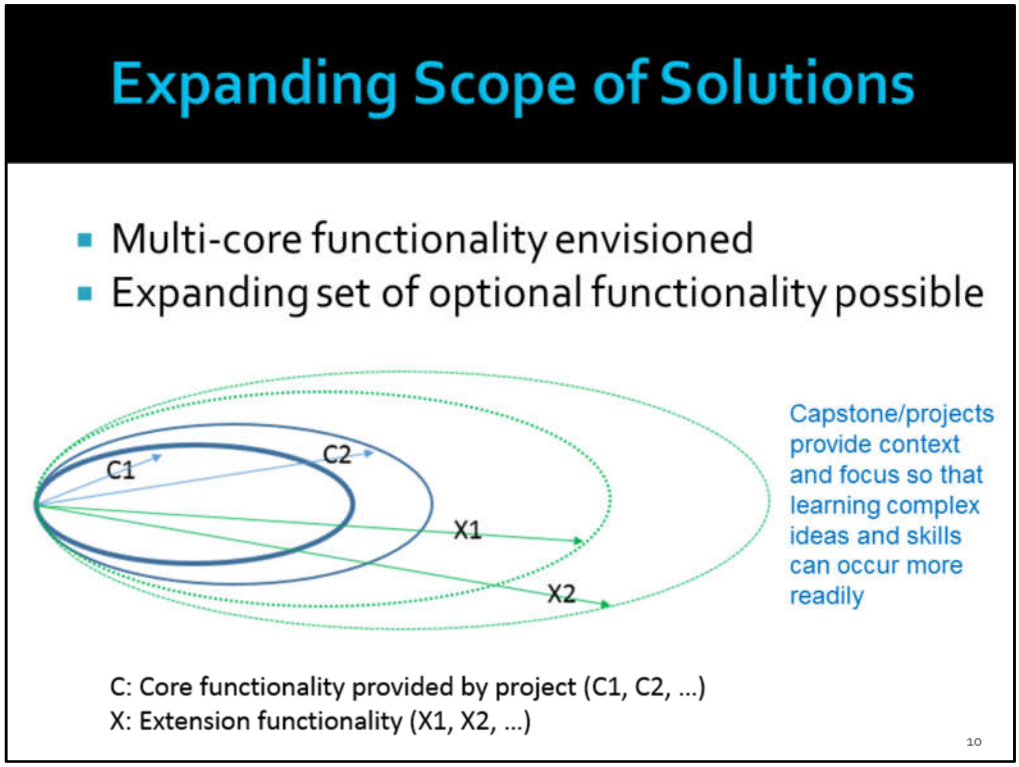
Immersion in projects

A multi-phase project core is strongly encouraged for each project, as this allows for early building and testing of prototypes. This, in turn, can provide key information about the viability of the project itself. It allows student to make progress on their core project goals without being sidetracked by mutually competing design considerations not vital to the project's success.

With the project consisting of a strong multi-level core and extensible phases, the completion of each phase denotes both a solution for the current one, as well as a launching pad for the next phase. It can also serve as a safety net – a pre-established return point to a previous level in case one is needed. The solution of each phase thus seeds subsequent phases of the project. Students first complete the core functionality and then continue working on optional extensions.

While a solution implies the existence of a problem, issue, or concern, the mere existence of a problem does not imply a solution is achievable or that it even exists.

Solution-based Learning (SBL)



Students are encouraged to provide diagrams of any sub-systems used in the design and linkages or feedback between these. Visual representation of the project allows students to maintain a hierarchical big-picture view of the system, along with the close-up view of specific sub-systems. Maintaining both these viewpoints simultaneously is useful in testing and troubleshooting project prototypes.

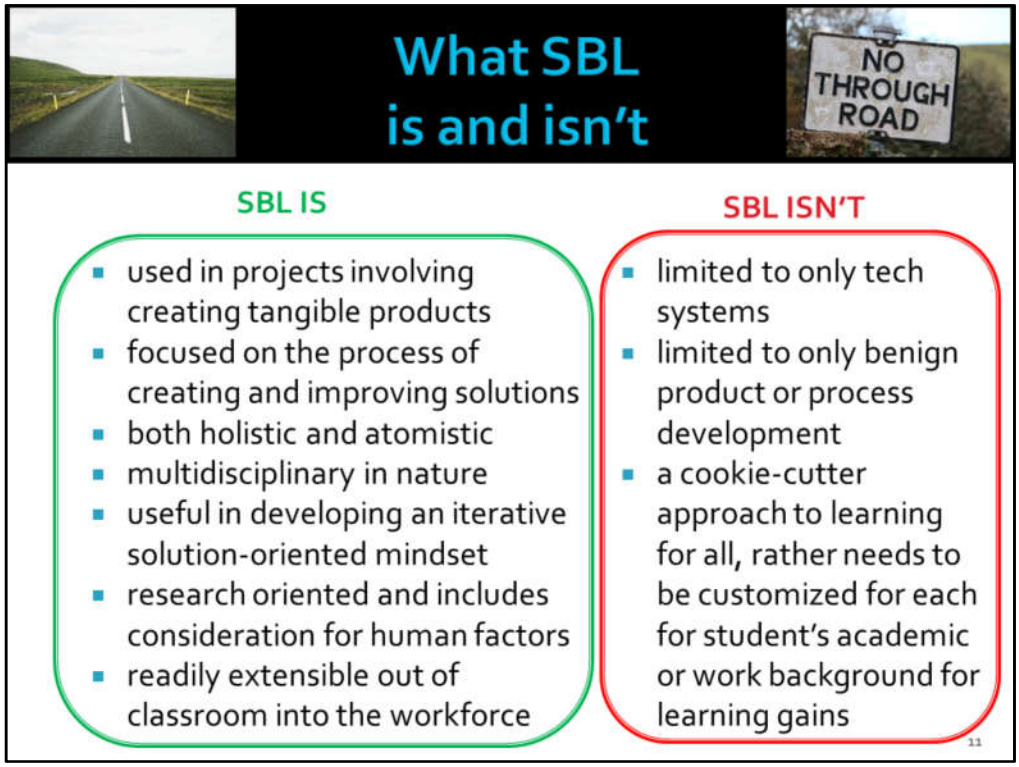
What functionality would you put in the innermost ellipse which would signify the completion of a key part of the design project, the one after that, and so on …

The positive, learning-focused, online-research, and solution-based approach used while developing their capstone project helps students develop innovative, personally customized extensions to existing products.

While developing solutions, it is important to designate key or core functionality upfront. This serves as a way to clearly identify success at each phase of the project. The enlarging range of functionality provided by a project can then readily be **tracked visually**.

Students are encouraged to keep improving on existing solutions, adding “good to have” features, along with the essential core functionality. Part of the initial planning process requires planning for future growth and new functionality as time and other resources permit. It builds on the “Model for Improvement” suggested as part of the Plan-Do-Study-Act cycle by closely questioning what one is trying to accomplish, raising questions about the changes that can be made which will result in improvement, and identifying whether a change is really an improvement.

Where’s Pluto?!



Ah, the open road, the feeling that the sky's the limit.

And still we need to start someplace meaningful.

No easy button though, a lot of effort is required.

Needs relearning "online research" beyond Googling, bibliographic databases, effective search strategies, patents, …

Focus on early and sustained success as evidenced by working solutions through all phases of a project.

Learning not isolated from experience but grows out of experience," along with the idea that such, "Learning is not fragmented but holistic."

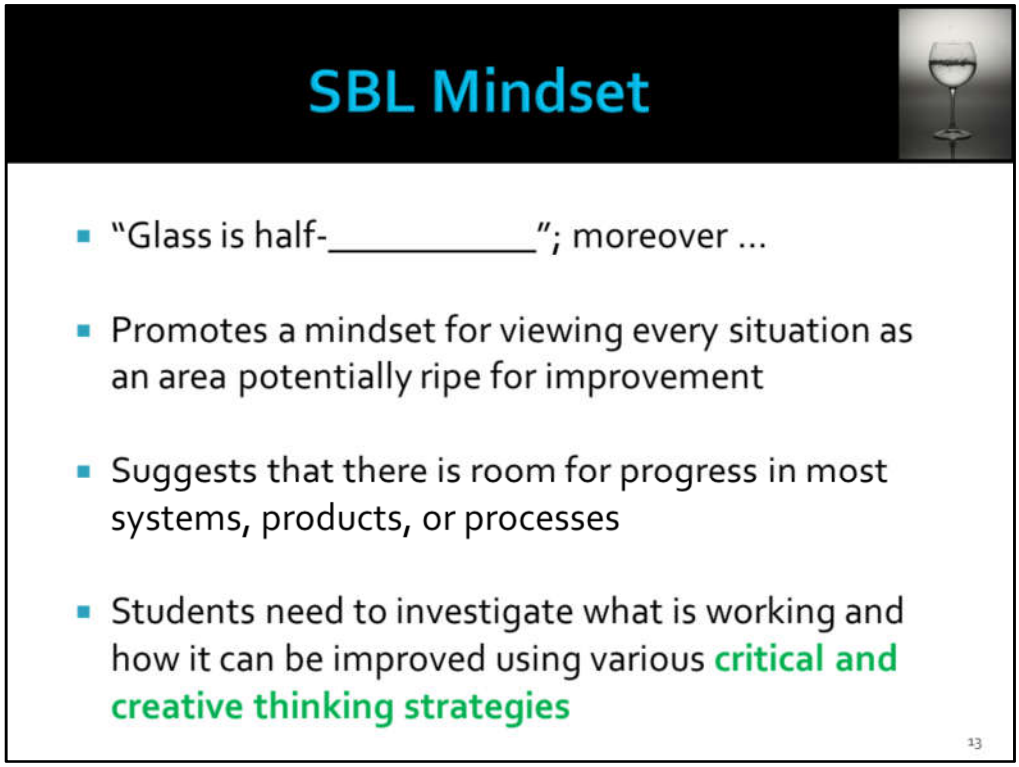
Actions informed by research taking into consideration human factors such as aesthetics, preferences, very human quirks

Tradeoffs

Feeling responsible for more than what they are being held accountable for as part of the capstone project

Students are invited to continuously broaden and deepen the scope of the project after its core functionality has been met, making it a "labor of love," a project which has the potential to continue long after the course is completed.

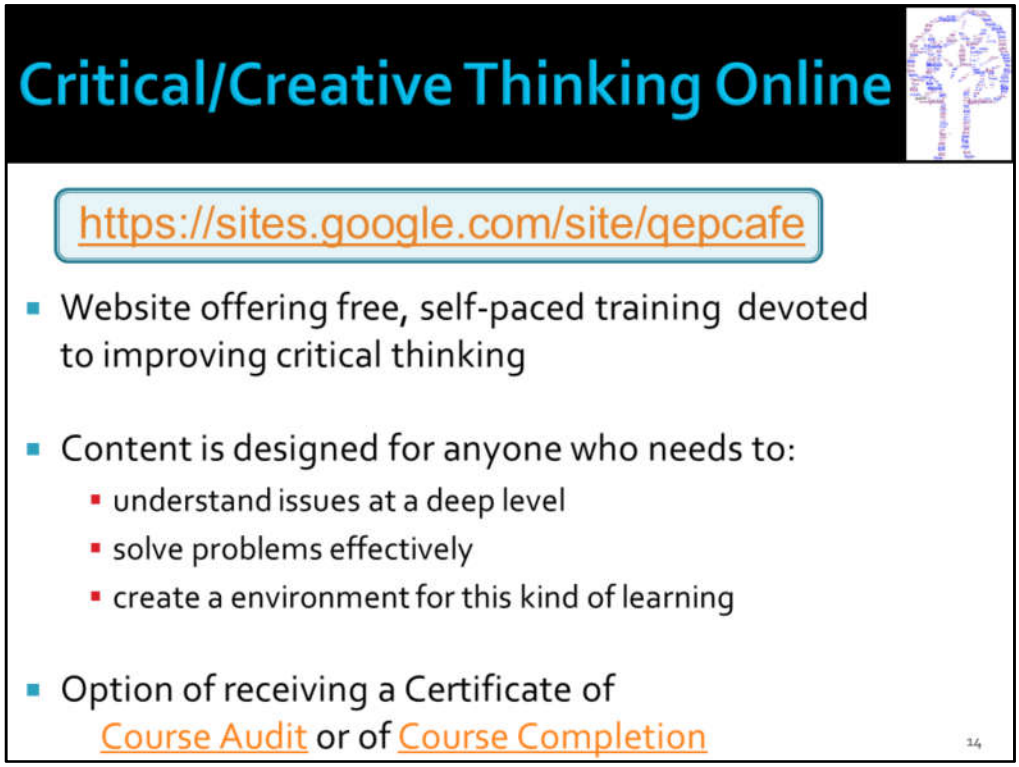
Allows students to regard the project as an advanced hobbyist activity, inviting them to be immersed for countless hours while trying to tinker, improve performance, and fix issues as these arise.



Provide a safe setting for students to tell their experiential stories. This allows students to step back and view the experience more objectively. They can understand it better in terms of perceptions and feelings and can be helped to challenge ways of thinking or acting that may be counter-productive for completing the project.

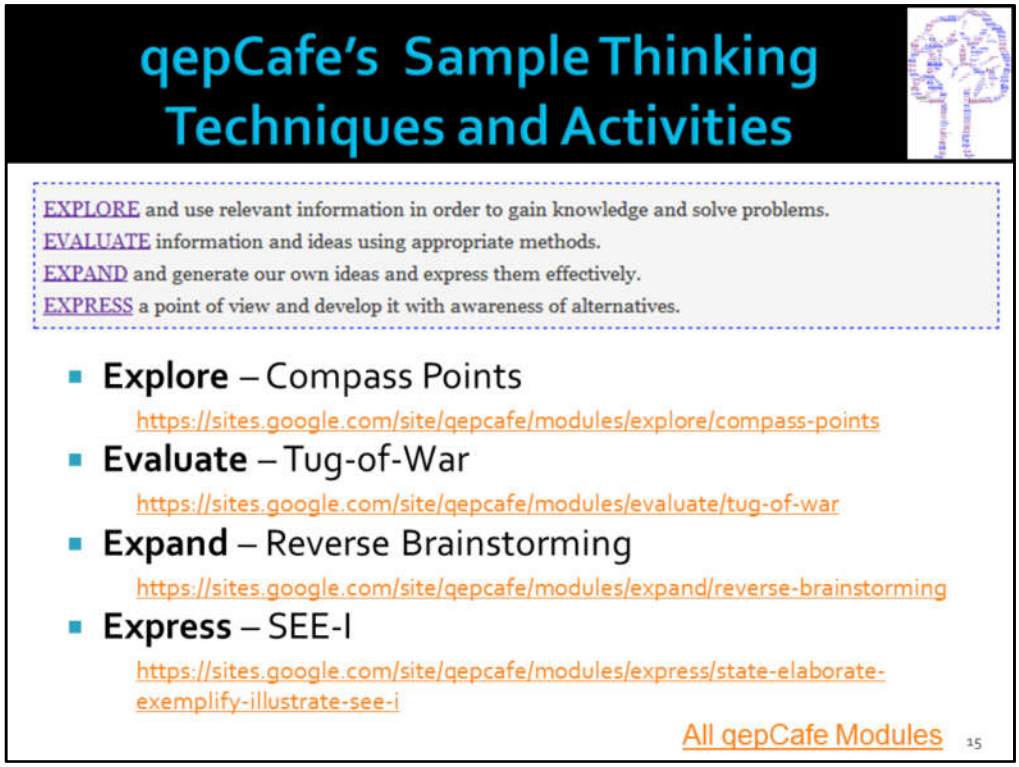
Empathetic communication.

Is that water or something more interesting!

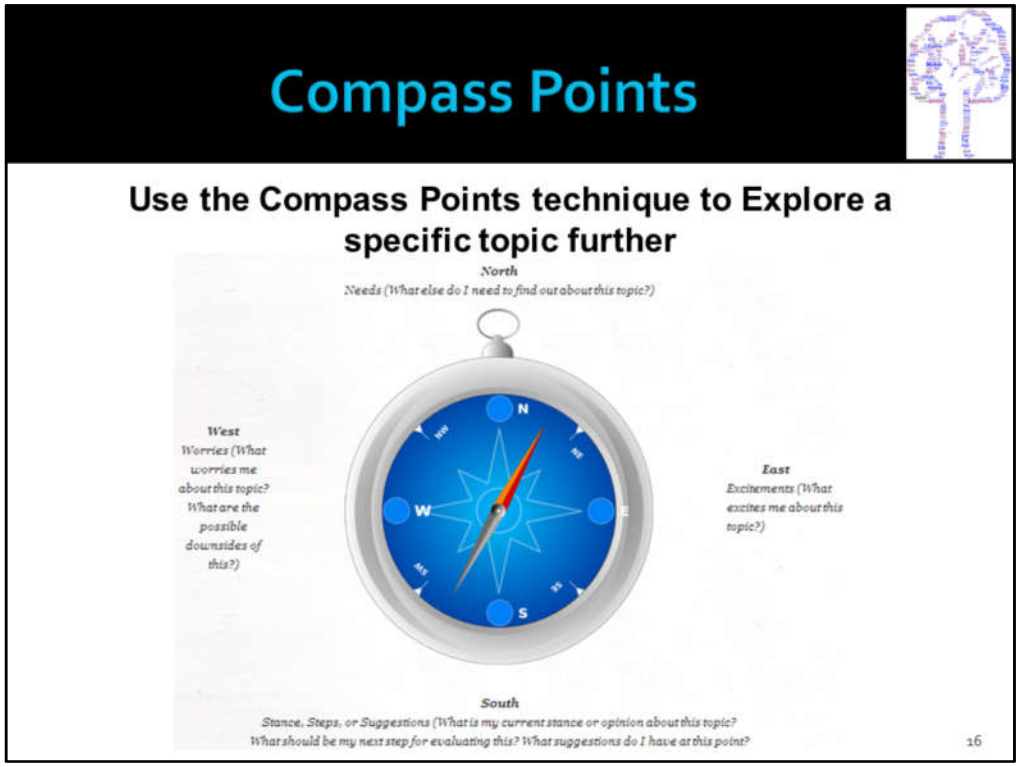


Critical/creative thinking website developed to support the Quality Enhancement Plan (QEP) for improving students thinking skills.

In order to familiarize students with various critical/creative thinking strategies, a free, online training resource, qepCafe, customized for electronic/computer technology, is being used. It includes various intellectual development theories and examples of practice which can be adapted for use in various settings. It encourages engaging with content at both a broader and a deeper level for solving problems effectively and for creating a supportive environment where this kind of learning can occur.



Additionally an overview module for reviewing different learning theories. When we understand how we learn, we can also learn how to do that better.



This 4-step process acts as a precursor to the Paul-Elder model of critical thinking used extensively in the capstone.

The E-W brings in emotion, intrinsic motivation for the project or item being investigated more closely.

Multi-step process rather than a rough-and-ready hastily put together untested solution

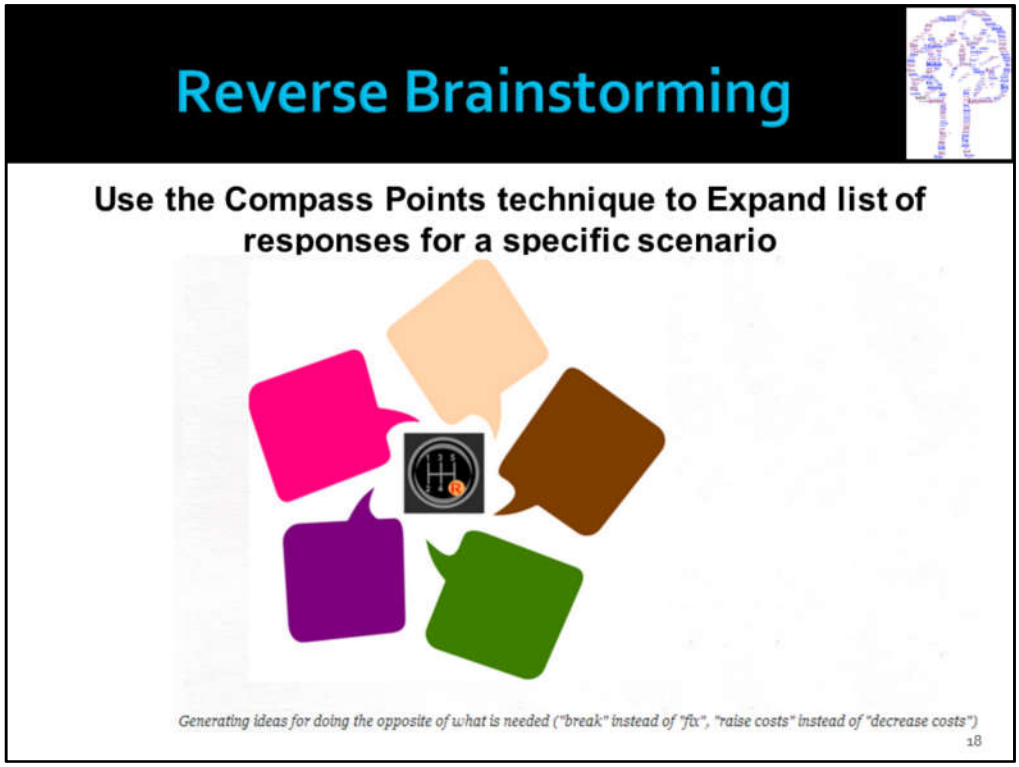
Tug-of-War

Use the Tug-of-War technique to Evaluate possible responses for a given scenario

Identify and weigh the different thoughts, ideas, or information regarding to a dilemma

17

Weighing competing criteria, not just number also relative size of each factor

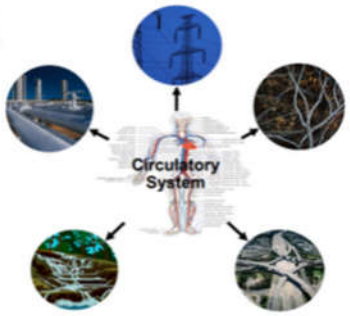


Instead of fixing things consider how to break them – then go back in and fix the ways in which it can be broken intentionally or unintentionally

SEE-I

Use the Compass Points technique to Express some aspect of the issue

	Comment
S	State. Say or write about the thing (topic, idea, fact, concept, etc.) succinctly
E	Elaborate. Paraphrase, providing additional details, using a phrase such as "In other words ... "
E	Exemplify. Provide a specific instance or representative member of a larger class of things. Counter examples of the concept may be provided as well.
I	Illustrate. Draw, act, depict, sketch, provide a word-picture, simile (compare often using "like" or "as"), metaphor, analogy



Tabular representation of the State, Elaborate, Exemplify-Illustrate (SEE-I) technique

19

1. **State** your main point: "I think….."
2. **Elaborate** on your main point in several sentences: "In other words……"
3. **Exemplify** or give an example of your main point: "For example……"
4. **Illustrate** or give an illustration of your main point: "It's like……" A picture or even a return demonstration of a skill

SEE-I for discipline specific competencies:

State: the Concept or discipline-related Skill

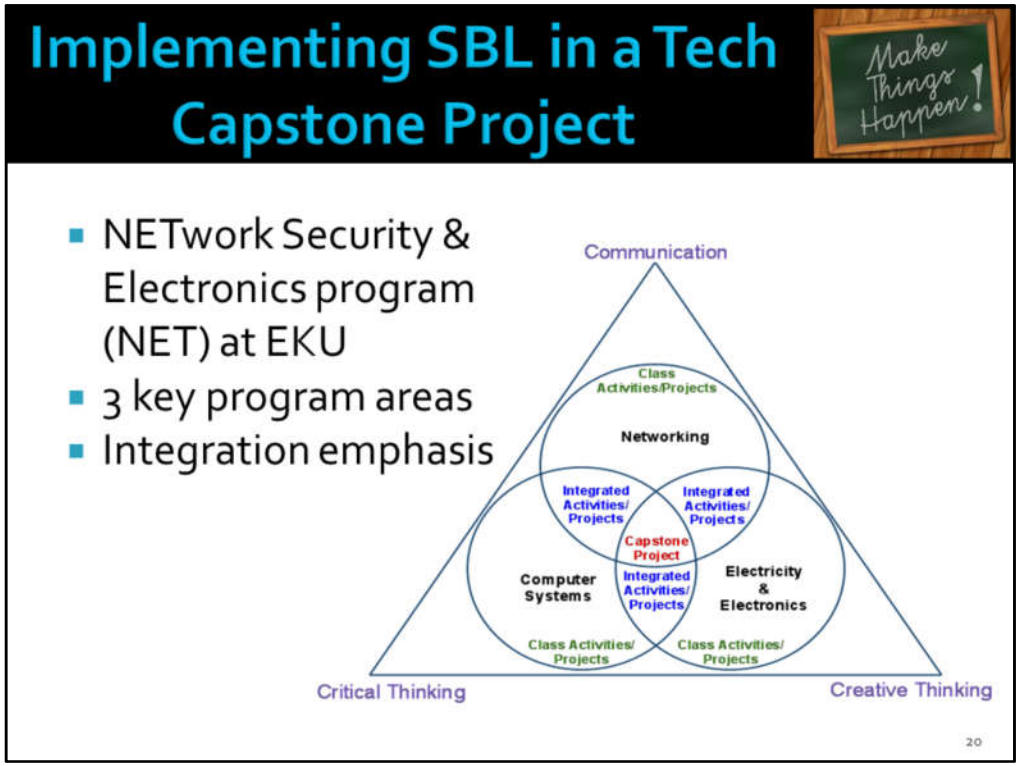
Elaborate: on the Skill and gather necessary equipment to successfully perform the skill

Exemplify :or verbally discuss the skill and how it is used in a specific discipline

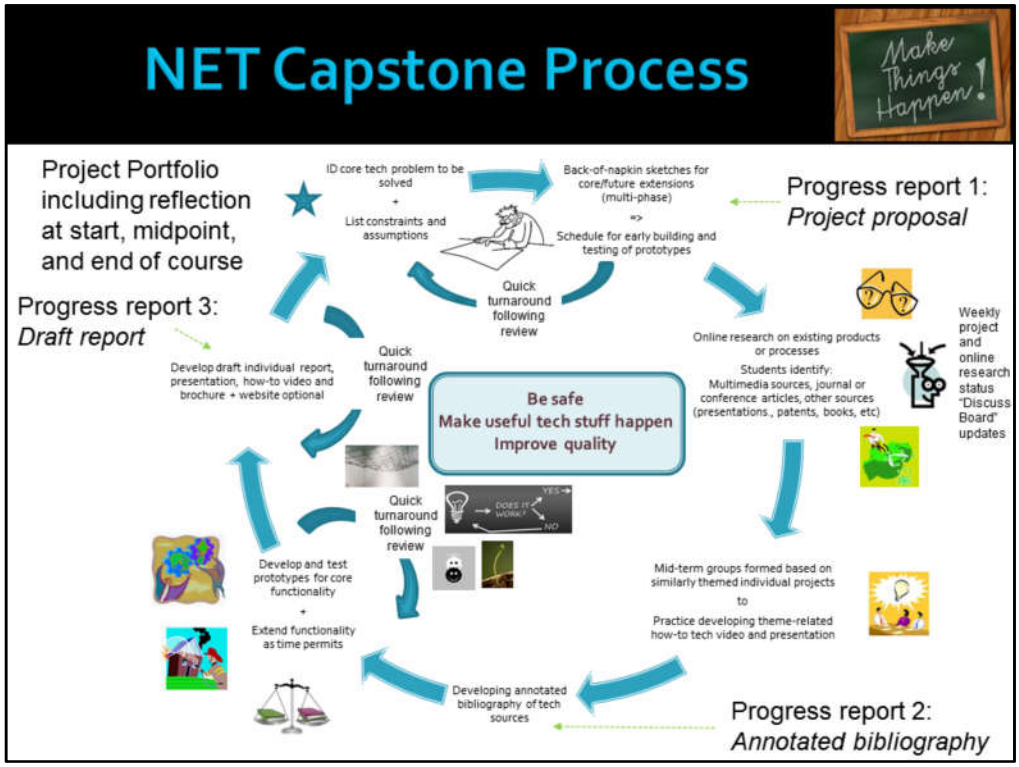
Illustrate: Perform the specific skill correctly

Let's Practice:

SEE-I the concept of **Critical Thinking** or a **concept central** to your course:



Developing a sense of personal ownership regarding the individual capstone project has been an overarching goal for the capstone course, alongside other student outcomes. This allows students to develop professional traits, including feeling responsible for more than what they are being held accountable for as part of the capstone project.



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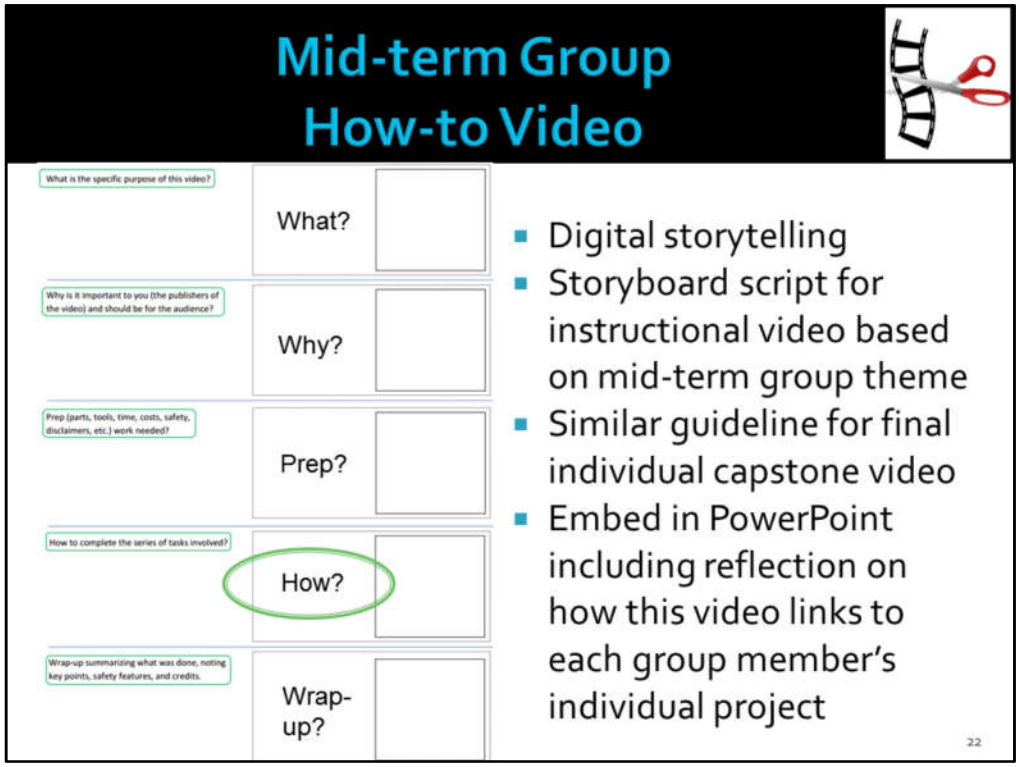
Visualizing linkages between various sections for organizing and prioritizing work

At the onset of the project, it is advisable to have clear understanding of what initially constitutes success, as would be evidenced by meeting a core set of features. Without this it would not be possible to conclude if a project has been successfully completed.

Since solutions are the goal, the final product at the end of each successful iteration serves as the initial state for the next one the process repeats. This is quite familiar to homeowners: By the time one is able to tick off all items on ones to-do list of home improvements, it is time to …

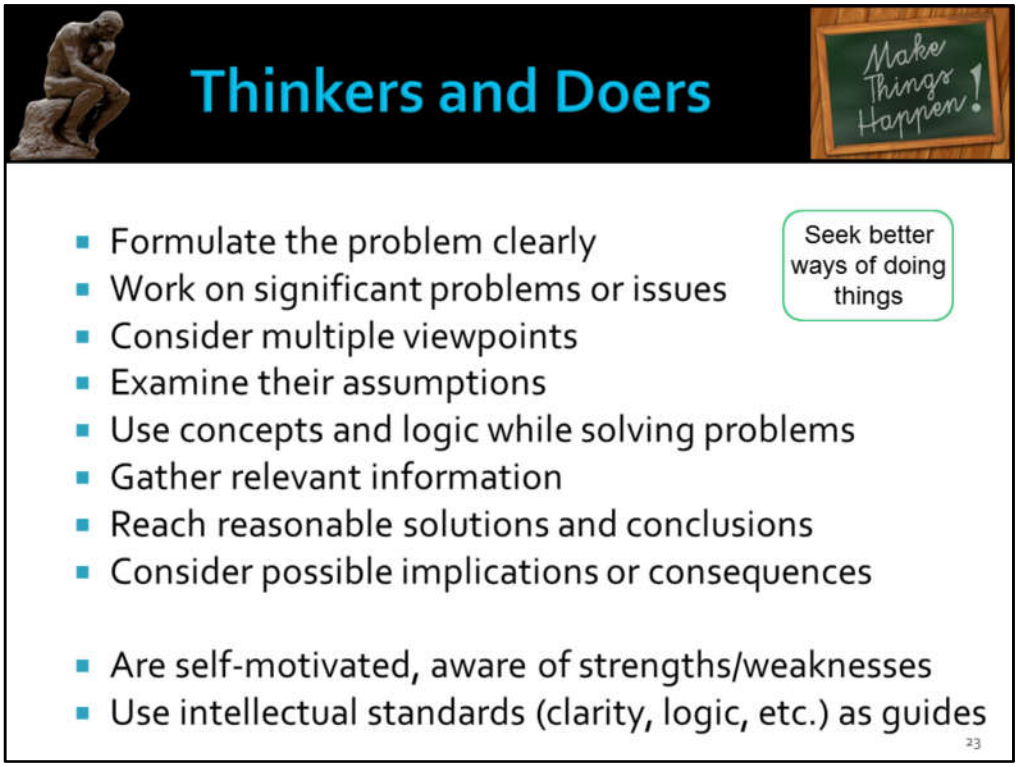
A tentative project schedule, including key milestones and sub-tasks within each, is developed. Overlaps between different segments of the project are identified for potential bottlenecks. Students delineate how the design is tested for compliance with its specifications. The free open-source project planning software Tom's Planner is frequently used for developing a project schedule. Early prototyping of the project is encouraged since success in developing prototypes that meet the core criteria can serve as a strong motivator through all phases of the project.

Exploratory research on work that has gone before: Quoting William Hull, artist Lee J. Ames, states, "If we taught children to speak, they'd never learn." He advises mimicry as a "prerequisite to creativity. It's wonderfully effective to imitate, copy, or trace what others have done in order to develop one's own tools," and then continue the process by developing something original.



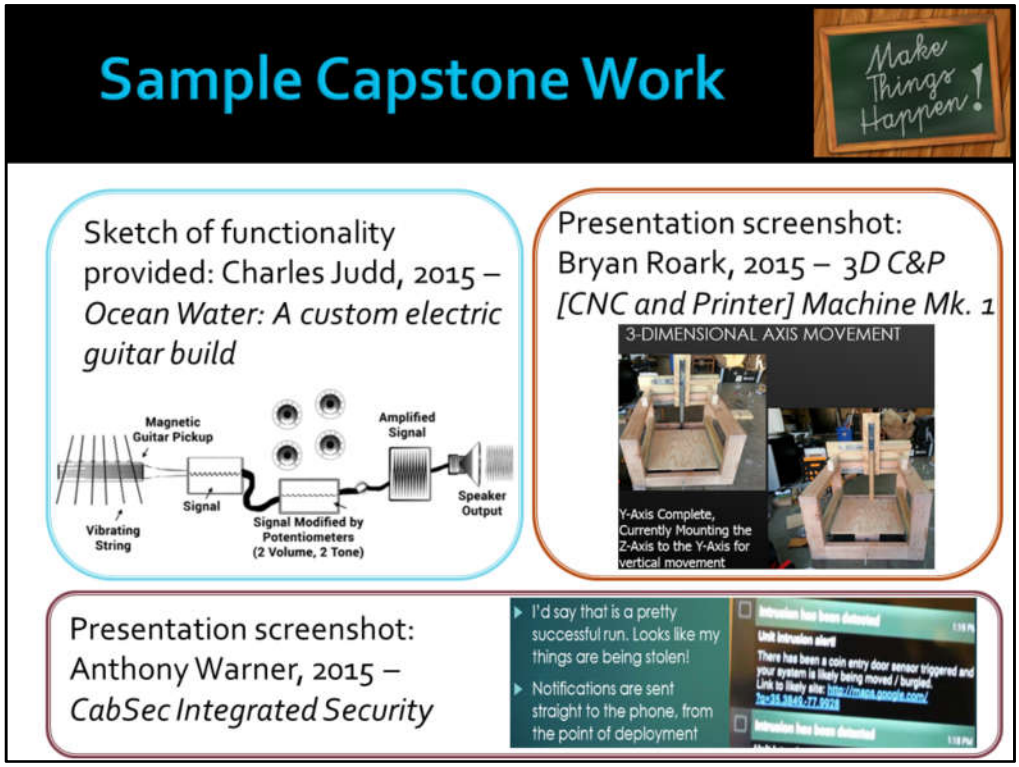
Digital Storytelling which includes, "point of view, a dramatic question, emotional content, the gift of your voice, the power of soundtrack, economy, and pacing."

In additional to being consumers of info they are also encouraged to become developers of it.



Know, do, be better thinkers and makers

More than just a way to write a report or develop a structured technical presentation – it is a way to think about and think through issues, scenarios, or problems – deepens and broadens our understanding of the problem, and appreciation of inter-relatedness of human structures/sysems.



Plenty of troubleshooting required:

Computing Technology Industry Association (CompTIA), which develops vendor-neutral professional certifications linked with various Information Technology (IT) areas, recommends a seven-step process[27] for tackling computer/network related issues. Here, it has been adapted for the capstone process as follows, with different project phases added in parenthesis, linking it with the Engineering is Elementary (EiE) design process:

Problem identification and information gathering: What, who, where, when, why, constrains, assumptions ("Ask" phase)

Formulate a theory to establish probable cause(s) of the problem ("Imagine" phase)

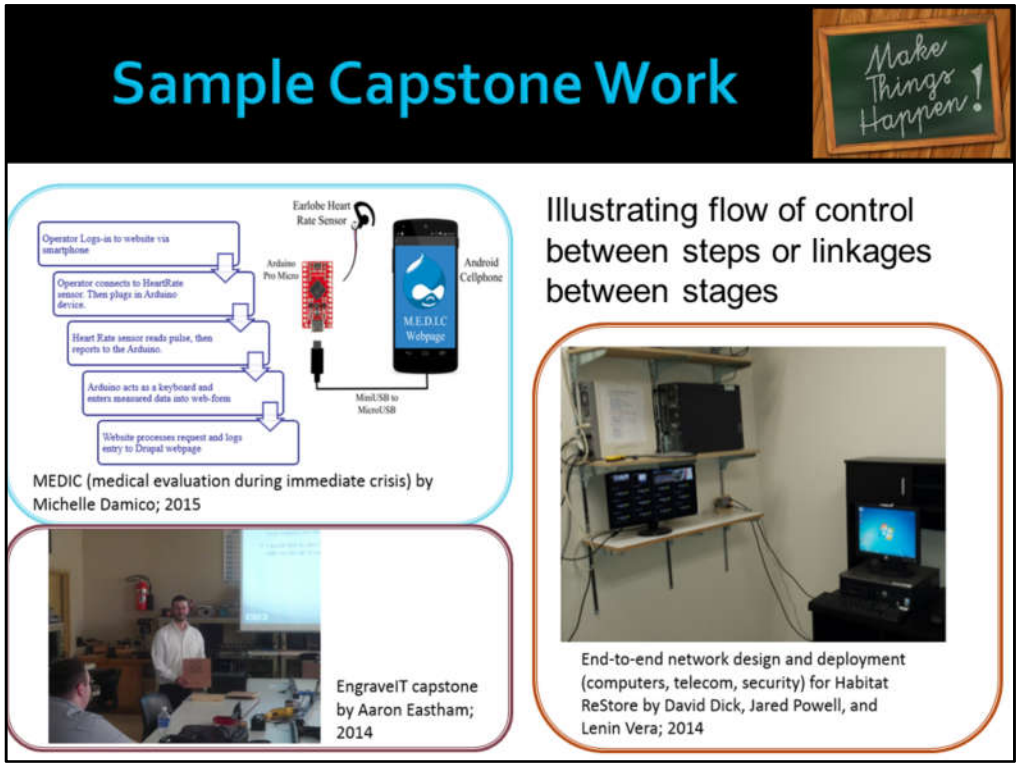
Identify suitable ways of testing the theory, and if not confirmed generate a new one ("Imagine" phase)

Develop a plan of action, along with identifying potential consequences ("Plan" phase)

Implement the plan ("Implement" or Prototype phase)

Verify that the solution is working, with no unintended adverse consequences, and update as needed ("Improve" phase which may link back to the Ask, Imagine, or Plan phases)

Document solution to inform/train users [suggest adding a "Tell" phase for sharing results following self- or group-reflection]



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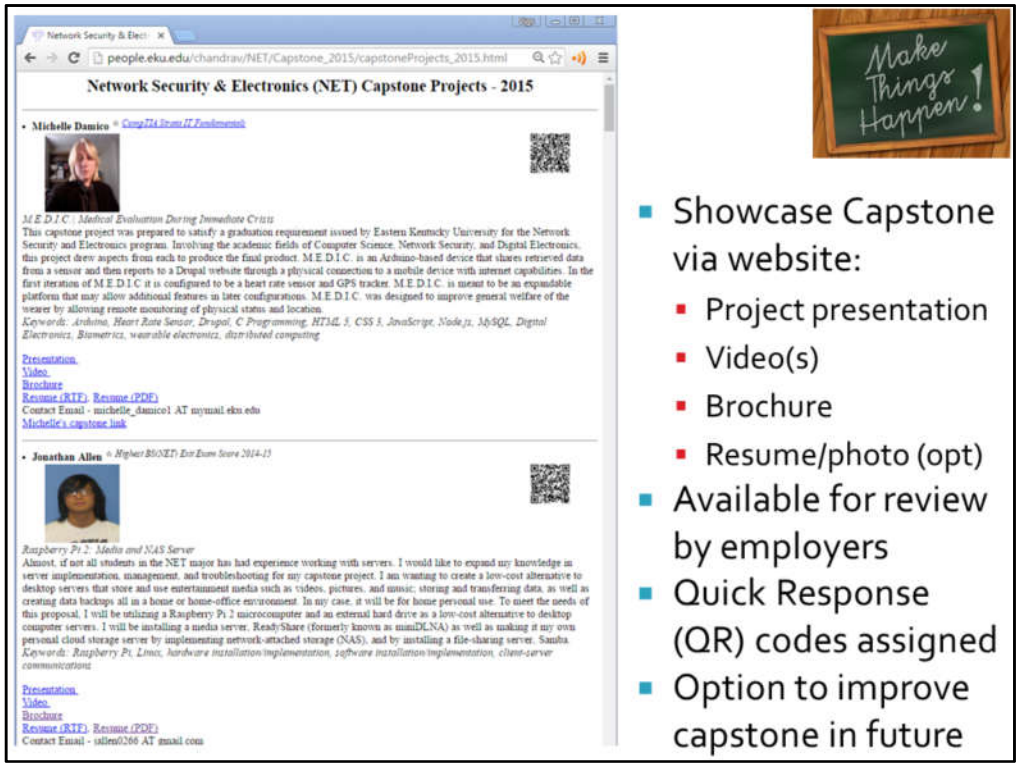
Innovative projects based on ongoing developments: see what’s happening, learn it and then build on it.

Innovative products rarely in a vacuum. Know the work that has gone before, mimic to gain a better understand, adapt, extend, and customize. Quoting William Hull, artist Lee J. Ames, states, “If we taught children to speak, they'd never learn.” He advises mimicry as a “prerequisite to creativity. It's wonderfully effective to imitate, copy, or trace what others have done in order to develop one's own tools,” and then continue the process by developing something original.



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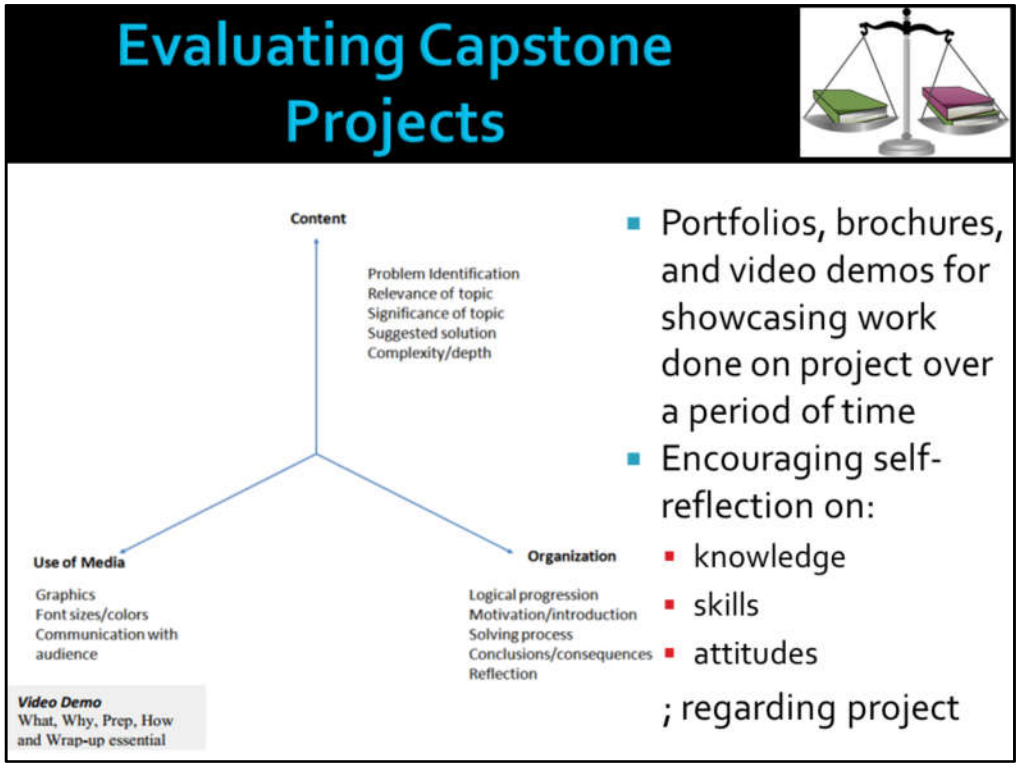
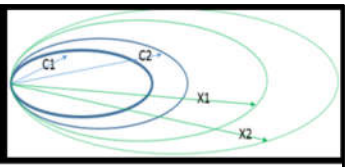


Instructor and peer feedback of the mid-term presentation is provided to student groups. Each student is required to note at least one thing which stood out about their fellow student's presentation and video, as well as at least one way in which it could be enhanced further. This allows students to build on their successes as well as on areas that require improvement.

Conclusions



- A new learning paradigm, SBL, proposed for keeping the focus on developing and refining solutions for a given system, situation, or scenario
- Inherently interdisciplinary nature of modern systems necessitates basing solutions on
  - existing research in the discipline
  - using critical/creative thinking effectively
  - active experimentation using prototypes
- Develops proactive mindset for improving systems

29

Students better prepared for tech workforce which are often project focused and team based

Discussion

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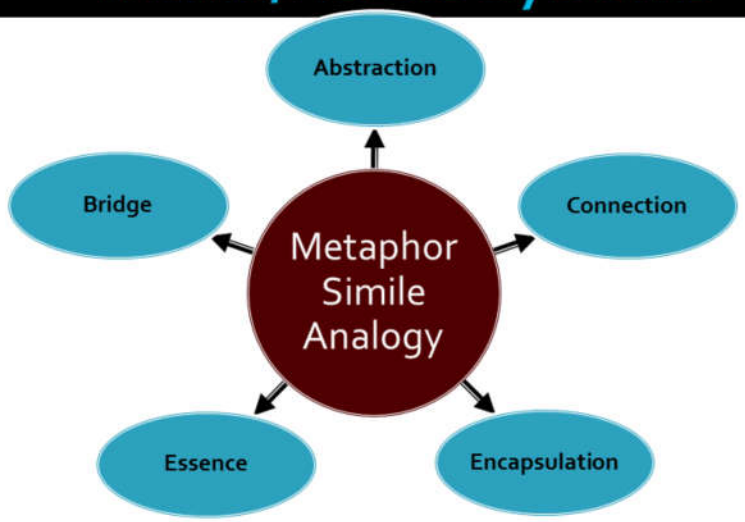
Draft version of ASEE conference presentation at http://people.eku.edu/chandrav website

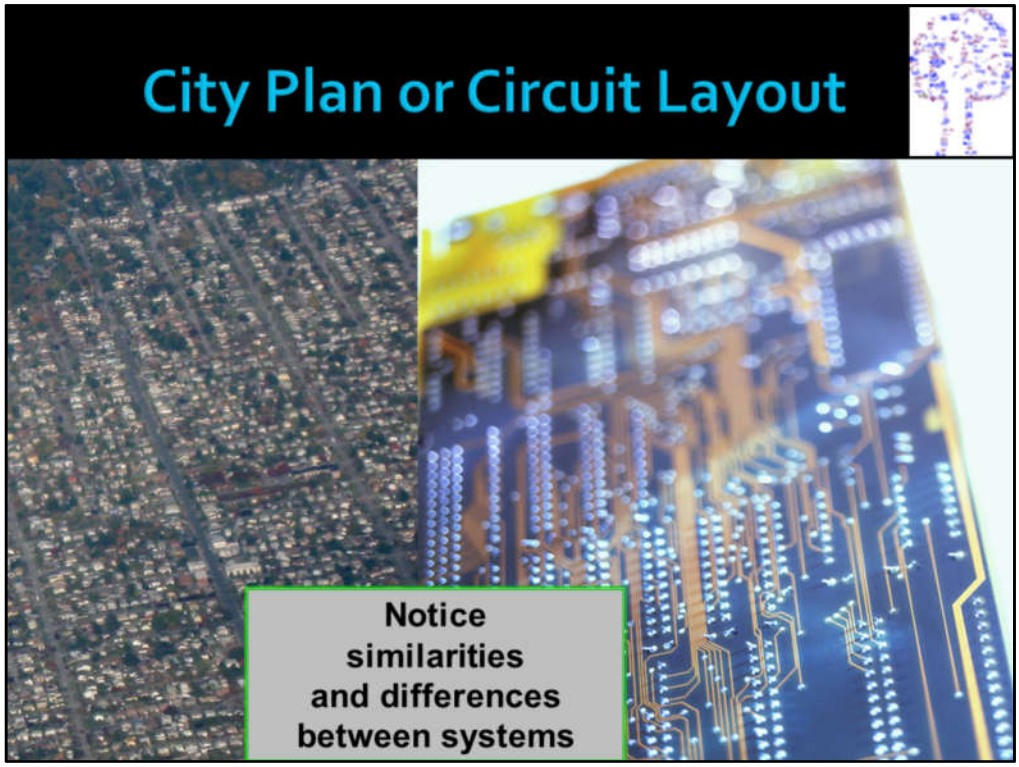
Making Connections Within/Across Systems



Metaphors can serve as an interesting context students relate to, from their own experiences or previous knowledge

31

City Plan or Circuit Layout



We also need to consider equivalent metaphors for …

One-ways

Traffic stops

Overpasses

Slower traffic

qepCafe Course Modules

§ Critical Thinking Training Course Modules

Overview	Explore	Evaluate	Expand	Express
Paul-Elder 's model of critical thinking	Compass Points	Defining Features Matrix (DFM)	I used to think ..., Now I think ...	State, Elaborate, Exemplify-Illustrate (SEE-I)
Bloom's taxonomy of learning objectives	Concept Teaching	Pro and Con Grid (PCG)	Positive, Minus, Interesting (PMI)	Circle of Viewpoints (COV)
Facione's APA expert consensus on critical thinking	See-Think-Wonder (STW)	Consequence & Sequel (C&S)	Connect-Extend-Challenge (CEC)	Six Thinking Hats
Notable education scholars -- Angelo & Cross, Brookfield, Perry, Huitt	Zoom In	Tug-of-War	Reverse Brainstorming	One Sentence Summary
Overview--Assessment	Explore--Assessment	Evaluate--Assessment	Expand--Assessment	Express--Assessment

qepCafe Certificate of Audit

This certificate of Critical Thinking Course Audit is awarded to

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For participating in all training modules and completing the pre-/post-surveys in the
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https://sites.google.com/site/qepcafe

Trainer: Prof. Vigs J. Chandra, Ph.D.
Date: July 4, 2012


qepCafe Certificate of Completion
This certificate of Critical Thinking Course Completion is awarded to
Casey Friend
For successfully completing all training modules and related assessments in the
CRITICAL THINKING ONLINE COURSE
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SAMPLE
Trainer: Prof. Vigs J. Chandra, Ph.D.
Date: July 4, 2012