Transforming Constraints into Opportunities

Re-envisioning Medical Education

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College of Medicine | College of Education
University of Central Florida

Professor Extraordinarious
Dept. of Financial Accounting
College of Accounting Sciences
University of South Africa (UNISA)

A Global Community – We're in this together.

112 Medical School Deans and Rectors

329 Faculty Members

71 Directors / CEOs

36 Instructional Designers & Curriculum Experts

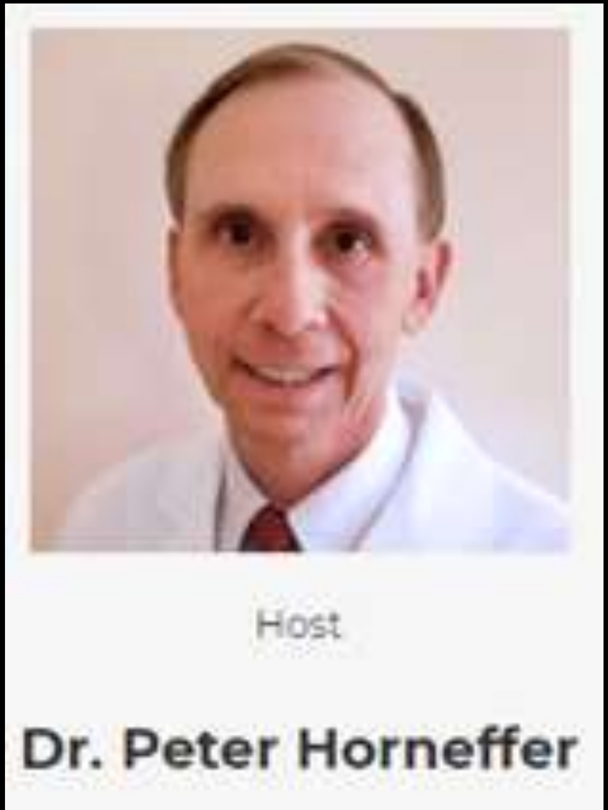
6 Faculty Development Experts

14 Education Consultants

29 Students

96 "Other"

Disclosures…



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Pre Pandemic

Post Pandemic

Epidemics, Pandemics lead to Reform

- Cholera – Improved sanitation and spurred vaccine development
- 1918-1919 Influenza epidemic (Spanish Flu) highlighted economic disparities. Led to improved housing and healthcare.

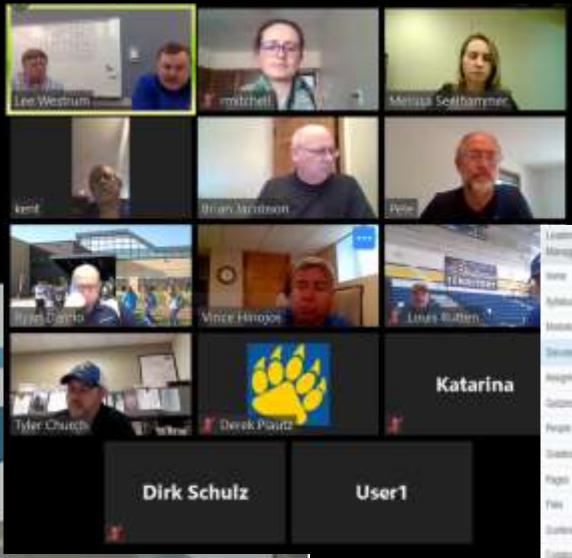
COVID 19
What will be its Silver Lining?

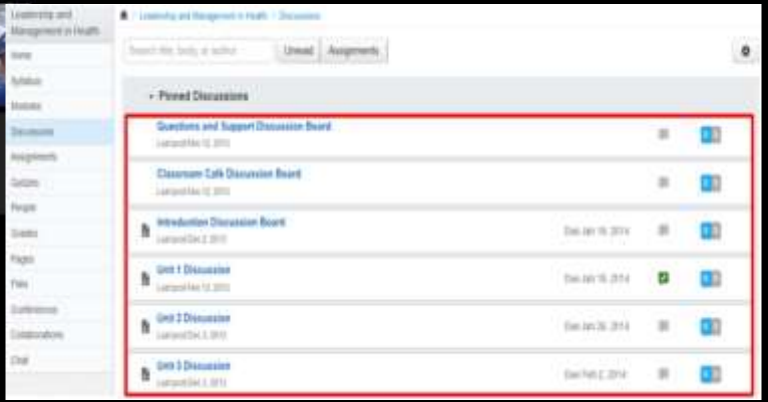
Emergency Remote Teaching

↓

Effective Evidence-Based Education

The Current Reality





What should we keep, improve & discard?

EVIDENCE-BASED MEDICINE

EVIDENCE-BASED LEARNING

Science of Learning

Credit

Feroza Daroowalla, MD, MPH
Associate Professor
Dept. Medical Education
College of Medicine
University of Central Florida

Practices pulmonary, critical care and palliative medicine

Transforming the Current Reality

One Framework: Evidenced-Based Medical Education

Table 1. Comparing the practice of Evidence-Based Medicine (EBM) and Evidence-Based Medical Education (EBME)

EBM	EBME
1. Articulate Patient's Needs	1. Articulate Curricular Needs
2. Ask Questions	2. Ask Questions
3. Acquire & Appraise Evidence	3. Acquire & Appraise Evidence
4. Apply Evidence	4. Apply Evidence
5. Assess Impact	5. Assess Impact

Transforming the Current Reality

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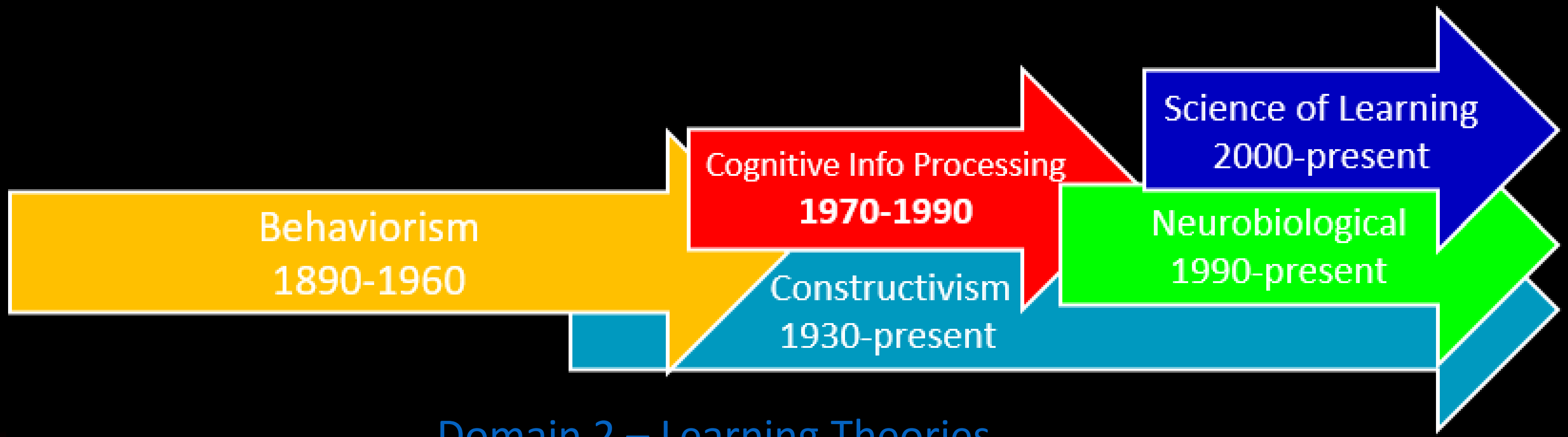
Transforming the Current Reality (3. Acquire Evidence)

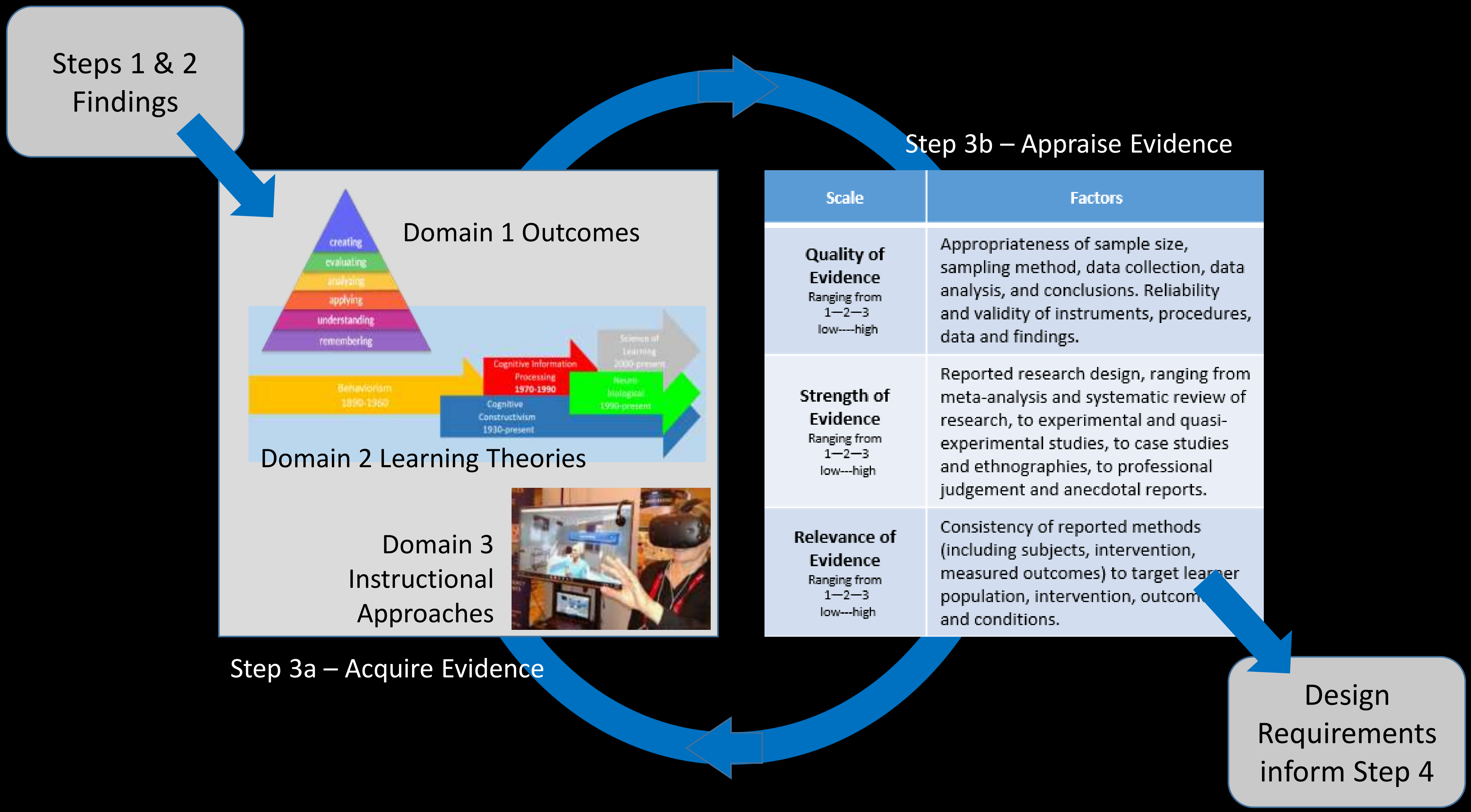
Domain 1 – Outcomes



Domain 2 – Learning Theories

Domain 3 – Instructional Approaches

Figure 1. Domains of Evidence



Steps 1 & 2 Findings
Domain 1 Outcomes
creating
evaluating
analyzing
applying
understanding
remembering
Behaviorism 1890-1960
Cognitive Information Processing 1970-1990
Cognitive Constructivism 1930-present
Neuro biological 1990-present
Science of Learning 2000-present
Domain 2 Learning Theories
Domain 3 Instructional Approaches
Step 3a – Acquire Evidence
Step 3b – Appraise Evidence

Scale	Factors
Quality of Evidence Ranging from 1—2—3 low----high	Appropriateness of sample size, sampling method, data collection, data analysis, and conclusions. Reliability and validity of instruments, procedures, data and findings.
Strength of Evidence Ranging from 1—2—3 low---high	Reported research design, ranging from meta-analysis and systematic review of research, to experimental and quasi-experimental studies, to case studies and ethnographies, to professional judgement and anecdotal reports.
Relevance of Evidence Ranging from 1—2—3 low---high	Consistency of reported methods (including subjects, intervention, measured outcomes) to target learner population, intervention, outcomes and conditions.

Design Requirements inform Step 4

Transforming the Current Reality

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Transforming the Current Reality (4. Apply Evidence)

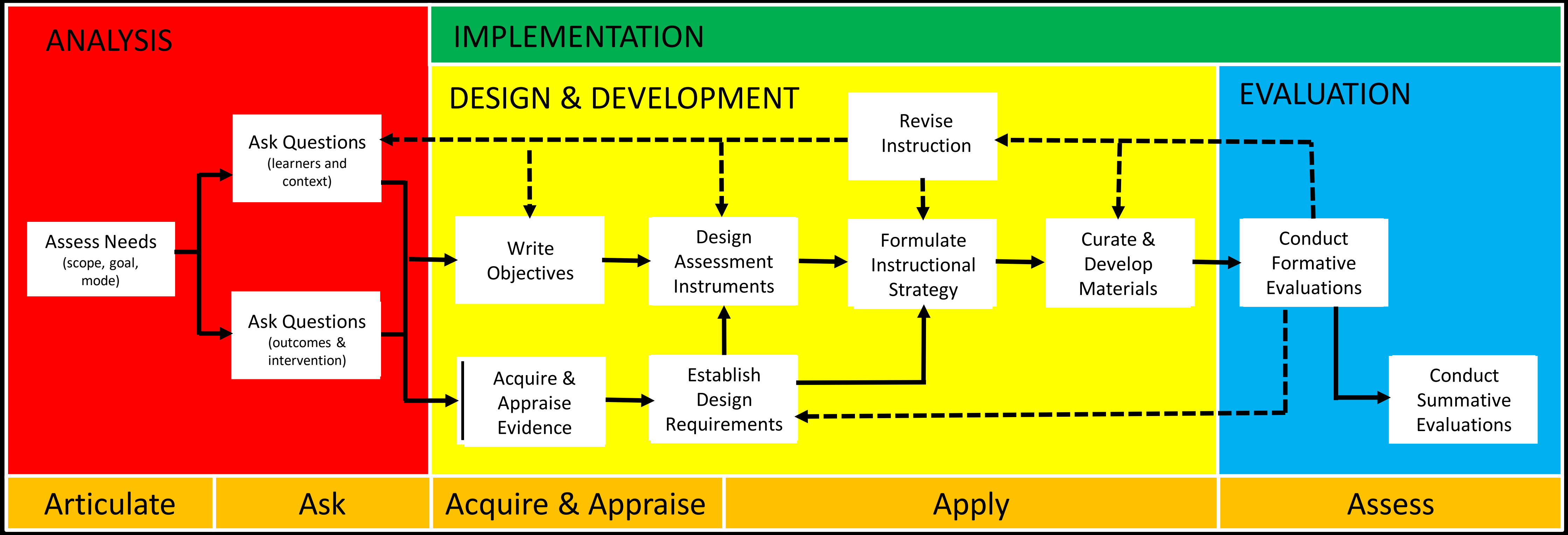


Figure 2. Key tasks associated with the systematic instructional design process

Transforming the Current Reality (4. Apply Evidence)

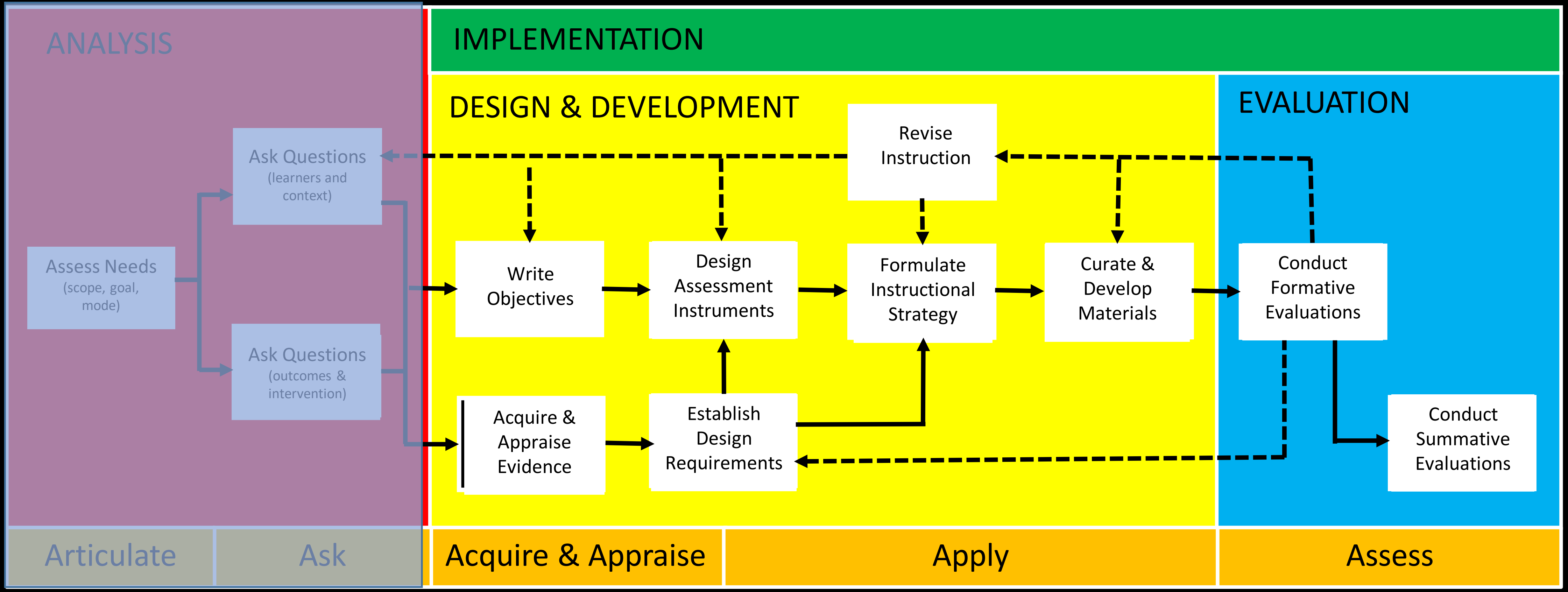


Figure 2. Key tasks associated with the systematic instructional design process

Transforming the Current Reality (4. Apply Evidence)

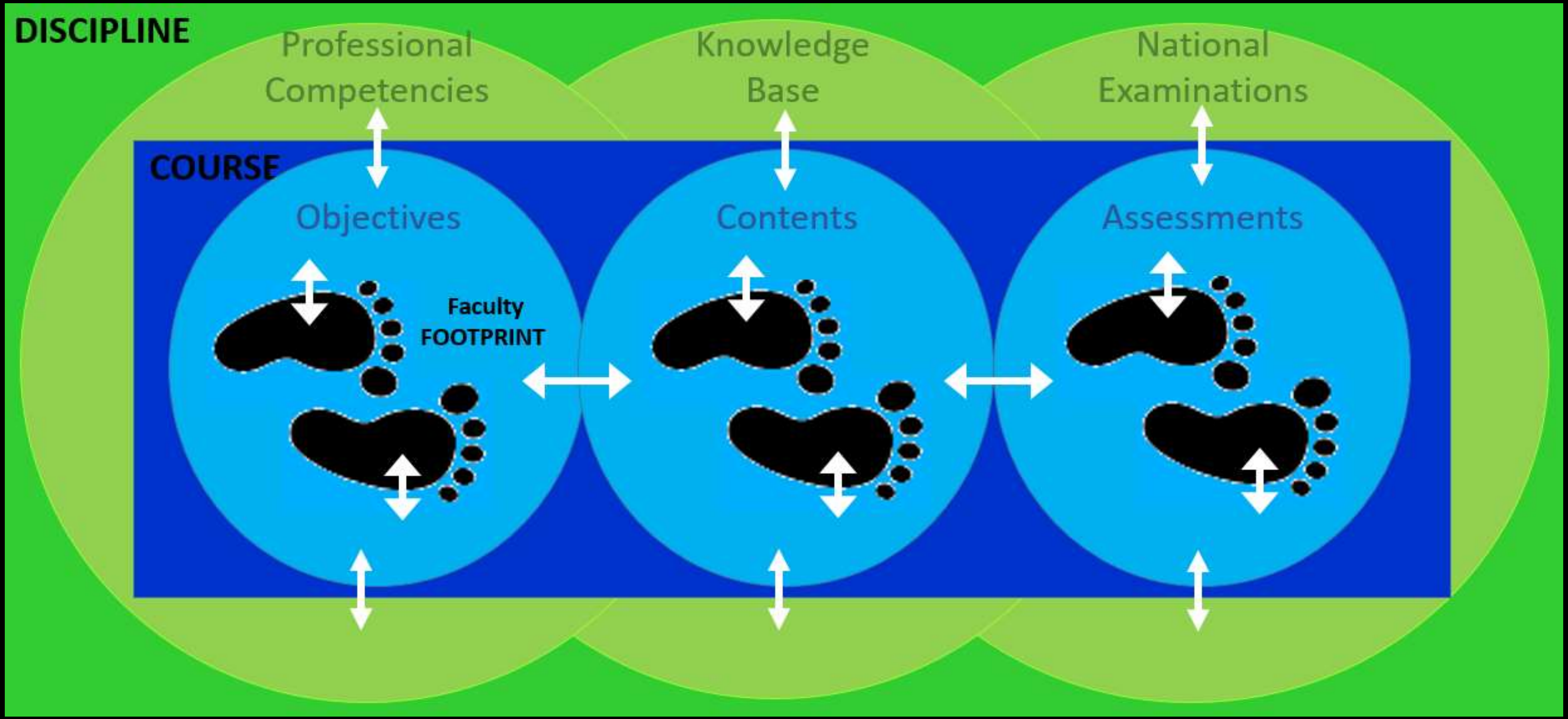


Figure 3. Alignment of fundamental instructional elements

Challenges with EBM & EBME

- Time
  - Access to educational research and literature
    - Time
      - Skills and knowledge necessary to ask questions, and acquire, appraise, and apply evidence
        - Time

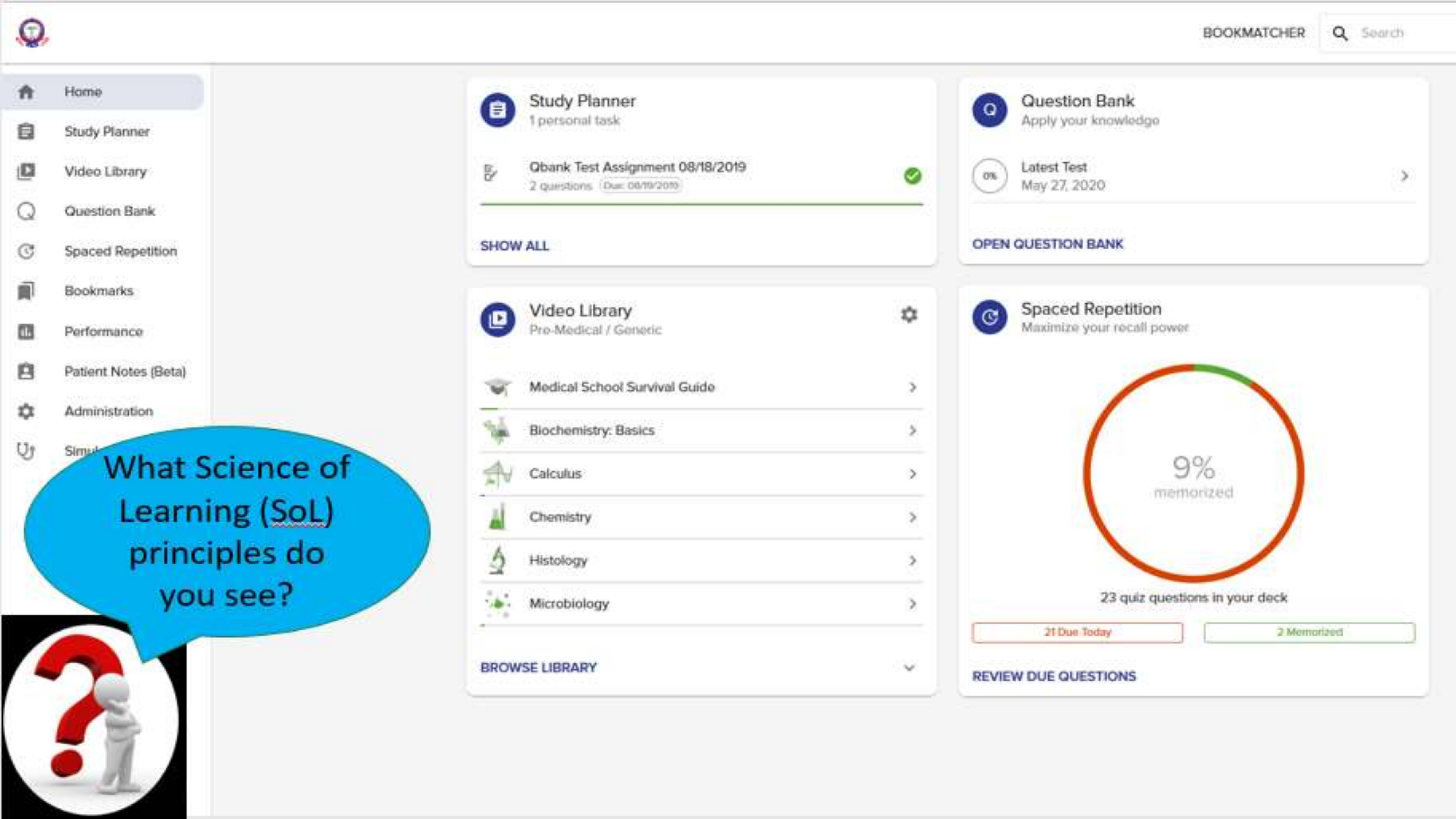
Resources for facilitating EBME

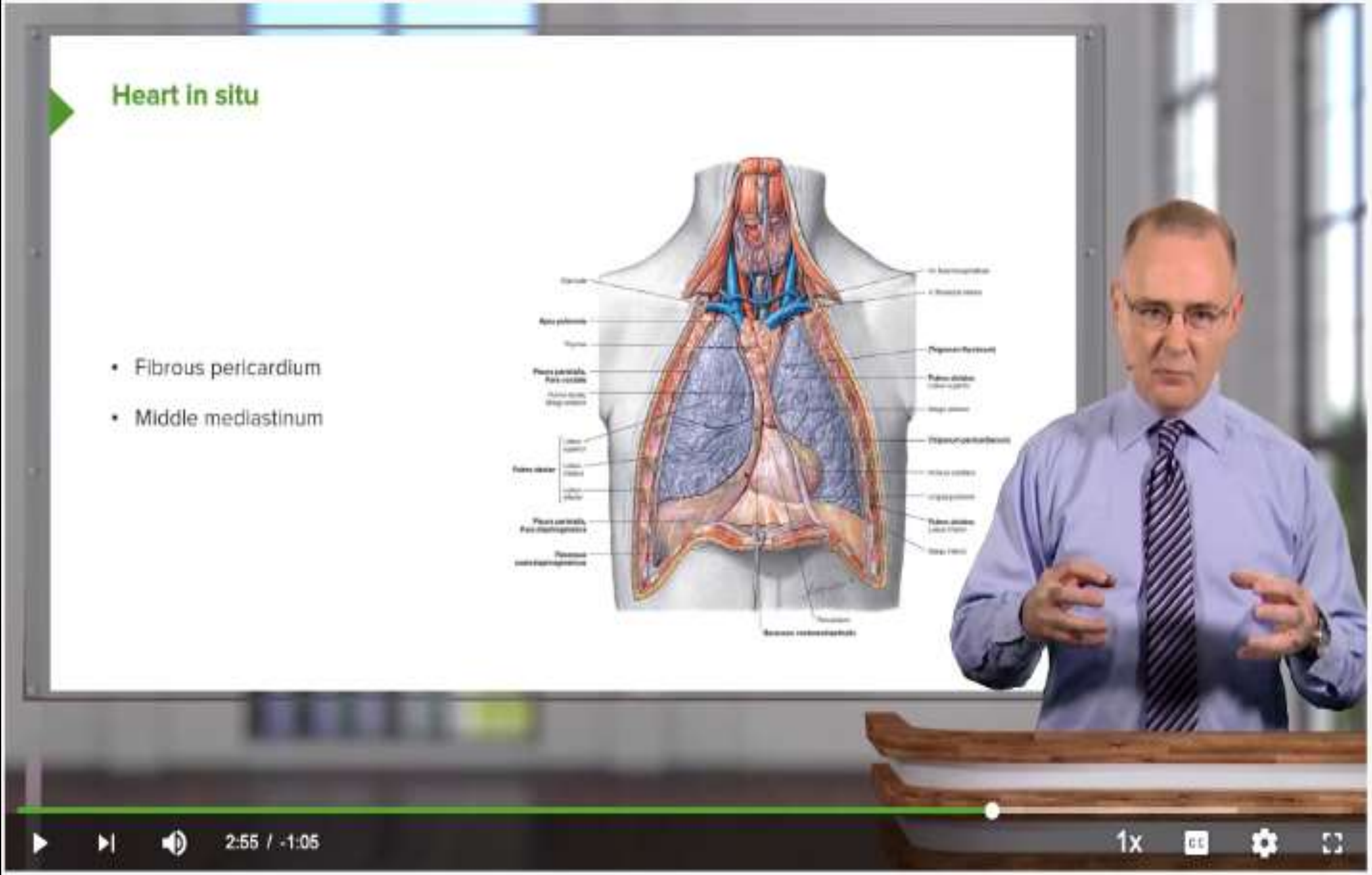
Instructional Designers

- Analyze learners, goals, context
- Define objectives
- Designing and aligning assessments and strategies
- Acquiring and appraising evidence
- Curating and development materials.
- Aligning research, theory, and practice

Learning Platforms

- Curated high quality content
- Guided delivery
- Built-in evidence-based learning strategies and instructional design
- Data tracking and feedback
- Deliverable remotely !COVID-19!


BOOKMATCHER
Search
Home
Study Planner
Video Library
Question Bank
Spaced Repetition
Bookmarks
Performance
Patient Notes (Beta)
Administration
Simu
Study Planner
1 personal task
Qbank Test Assignment 08/18/2019
2 questions
Due: 08/19/2019
SHOW ALL
Question Bank
Apply your knowledge
0%
Latest Test
May 27, 2020
OPEN QUESTION BANK
Video Library
Pre-Medical / Generic
Medical School Survival Guide
Biochemistry: Basics
Calculus
Chemistry
Histology
Microbiology
BROWSE LIBRARY
Spaced Repetition
Maximize your recall power
9%
memorized
23 quiz questions in your deck
21 Due Today
2 Memorized
REVIEW DUE QUESTIONS
What Science of Learning (SoL) principles do you see?



In Situ View – Heart (Cor) by Craig Canby, PhD

ASSIGN

Bookmark 3D Model Transcript Materials Notes Report

3D Model

Thorax

The thorax is the region of the trunk that extends from the neck

Playlist
25 videos

- In Situ View – Heart (Cor)
- Pericardium and Pericardial Cavity – Heart (Cor)

SHOW PLAYLIST

Unanswered
96

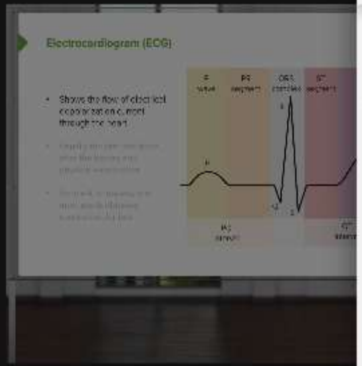
Due Today
3

Memorized
1

The T wave corresponds to which of the following?

- Junction between the end of the QRS complex and the start of the ST segment
- Ventricular repolarization
- Time from the start of atrial depolarization to the start of ventricular polarization
- Atrial repolarization
- Atrial depolarization

How sure are you about your answer?



Electrocardiogram (E
Interpretation

0 of 44 topics completed

0 of 44 videos watched

4 of 100 questions answered

ASSIGN

Educators

Joseph Alpert, MD
Tucson University, Arizona, USA

Standard 12 Lead ECG
1 quiz question

0% memorized

Unanswered 96 | Due Today 2 | Memorized 2

The T wave corresponds to which of the following?

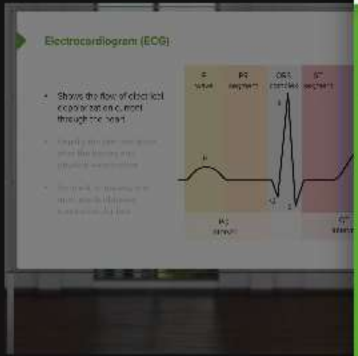
- Junction between the end of the QRS complex and the start of the ST segment
- ✔ Ventricular repolarization
- Time from the start of atrial depolarization to the start of ventricular polarization
- Atrial repolarization
- Atrial depolarization

WATCH RELATED VIDEO

GIVE FEEDBACK

✔ Correct! Memorized for 23 days!

NEXT



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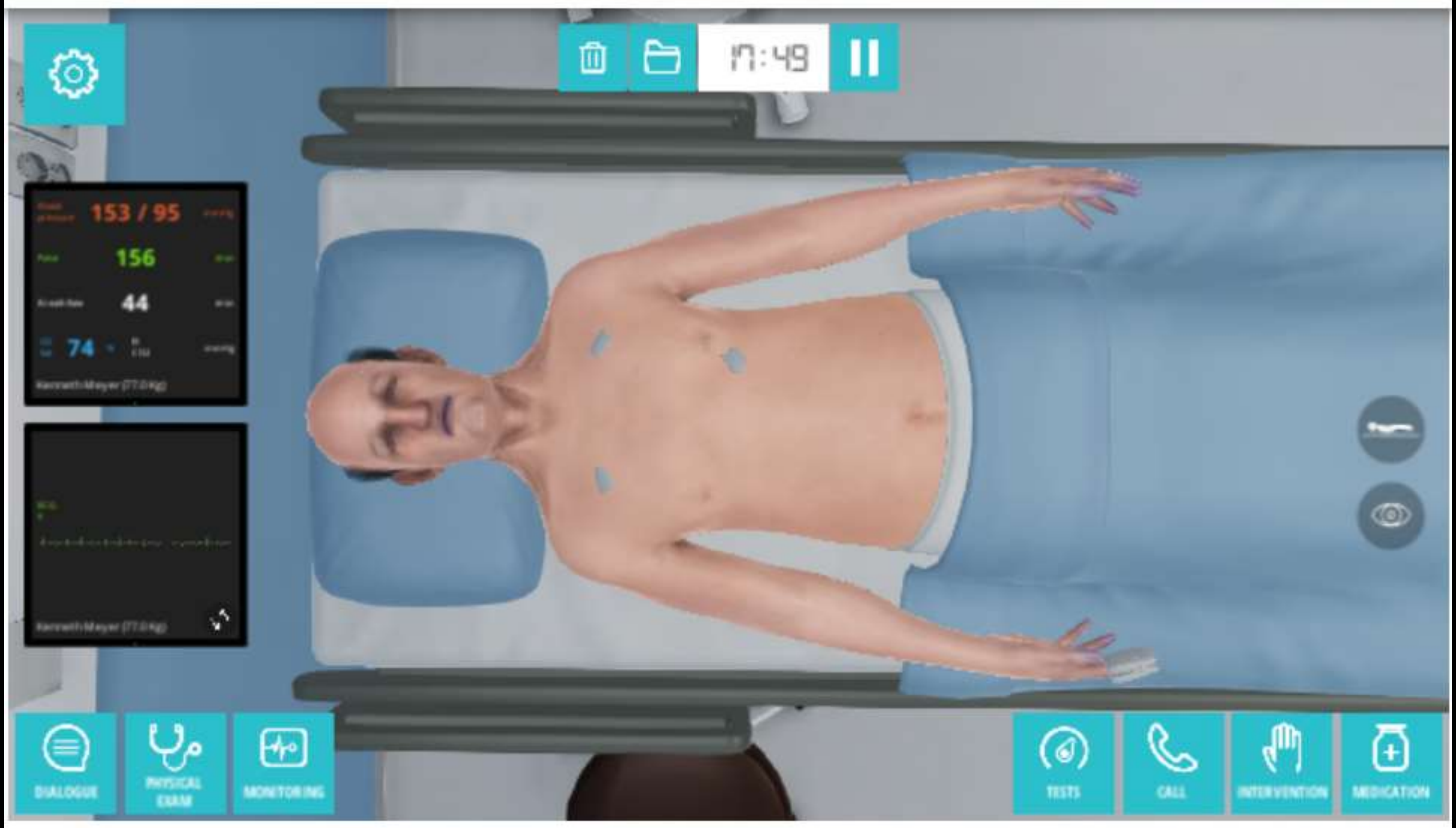

17:49
153 / 95
156
44
74
DIALOGUE
PHYSICAL EXAM
MONITORING
TESTS
CALL
INTERVENTION
MEDICATION

Six Fundamental Evidence-Based Learning Strategies

- Pairing graphics with words
- Linking abstract concepts to concrete examples
- Alternating materials being studied- interleaving
- Spaced learning
- Assessing to boost retention
- Asking probing questions

(learningscientists.org)

All American Institute of Medical Sciences (AAIMS)

Jamaica

ADMINISTRATION

- Statistics
  - Users
  - Content
  - Qbank
  - Dashboard
- Content Management
- Assignments
- Patient Notes (Beta)
- User Management
- Settings

CONTENT VIEW

- Home
- Video Library

User Statistics

May 30, 2019 - May 30, 2020

Active Users	Started Lectures	Answered Recall Questions	Answered Qbank Questions	Viewed Articles
187	73,893	242,727 61 % correct	10,612 60 % correct	500

Groups | Users

Name	Videos			Recall Questions		Articles	Qbank Questions	
	Started	Finished	Watched Minutes	Answered	% correct	Viewed	Answered	% correct
Admin	69	36	242	60	67 %	14	38	37 %
Clinical Rotations	4,365	4,128	21,736	4,051	85 %	4	2,129	61 %
Faculty Staff	869	338	2,618	1,924	76 %	68	1,064	79 %
MD 10	3,208	3,166	15,553	58	78 %	0	1,043	51 %
MD 11	3,278	3,248	15,811	361	73 %	0	914	51 %

Polling Questions

1. Do you think that medical education will emerge from the pandemic in an improved state?
2. Do the majority of your colleagues base their educational methods on evidence-based practices?
3. Do you currently have an instructional designer on staff to facilitate evidence-based education?
4. Do you employ a learning platform to facilitate curriculum delivery based on evidence-based practices?


COVID 19
What will be its Silver Lining?
Teacher Directed Methods & Materials
Active Student-Centered Learning
Image from: iridiumadvisors.com
no copyright infringement is intended

400 BCE

Image courtesy of the Alan Mason Chesney Medical Archives
of the Johns Hopkins Medical Institutions

1960 CE

2020 CE

What's wrong with teacher-directed methods and means?

Teacher-Directed Methods

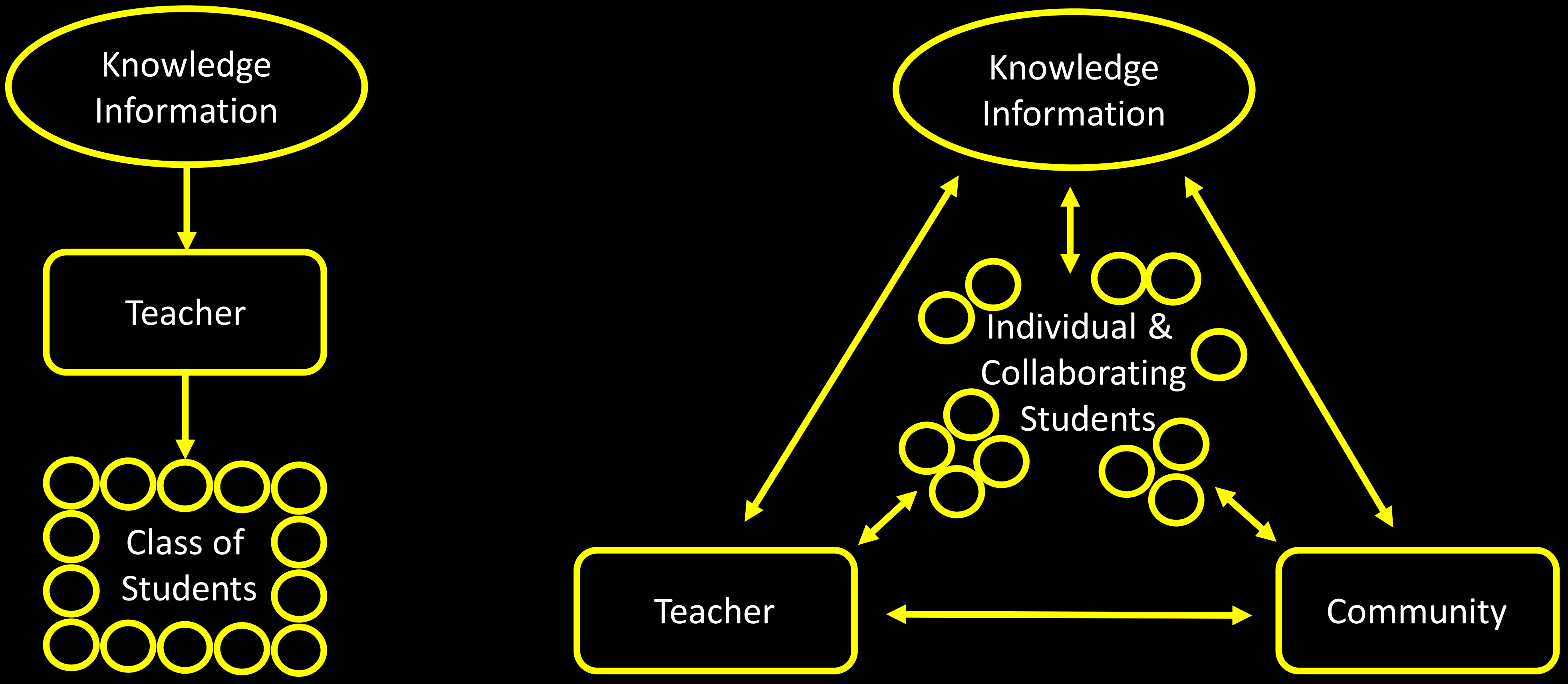
- PPT and text-based materials focus on the transmission of information
- Limited interactions result in feelings of isolation and anonymity
- Lack interactions to interpret and construct knowledge
- Inordinate use of precious synchronous time
- Based on speaking and listening, not necessarily engaging
- Fail to use potential technology

Teacher-Directed Methods

Without interactions, instruction may simply become "passing on content as if it were dogmatic truth, and the cycle of knowledge acquisition, critical evaluation and knowledge validation, that is important for the development of higher-order thinking skills, is nonexistent."

(Shale & Garrison, 1990, p. 29)

Active Student-Centered Learning (Table)

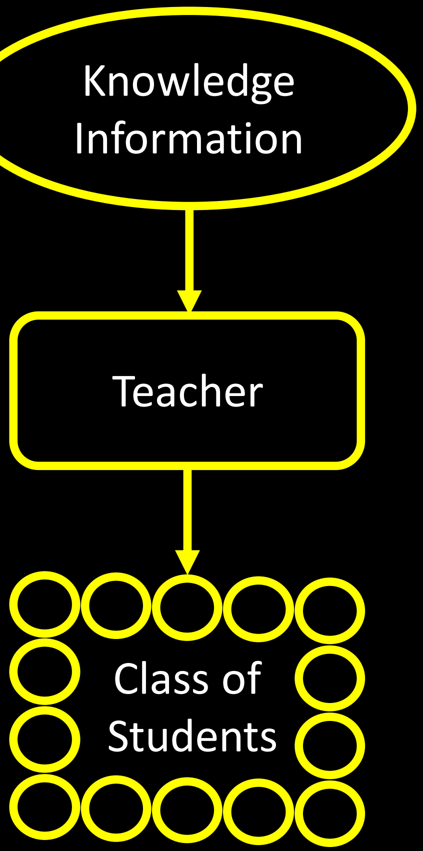


Teacher-Directed Learning

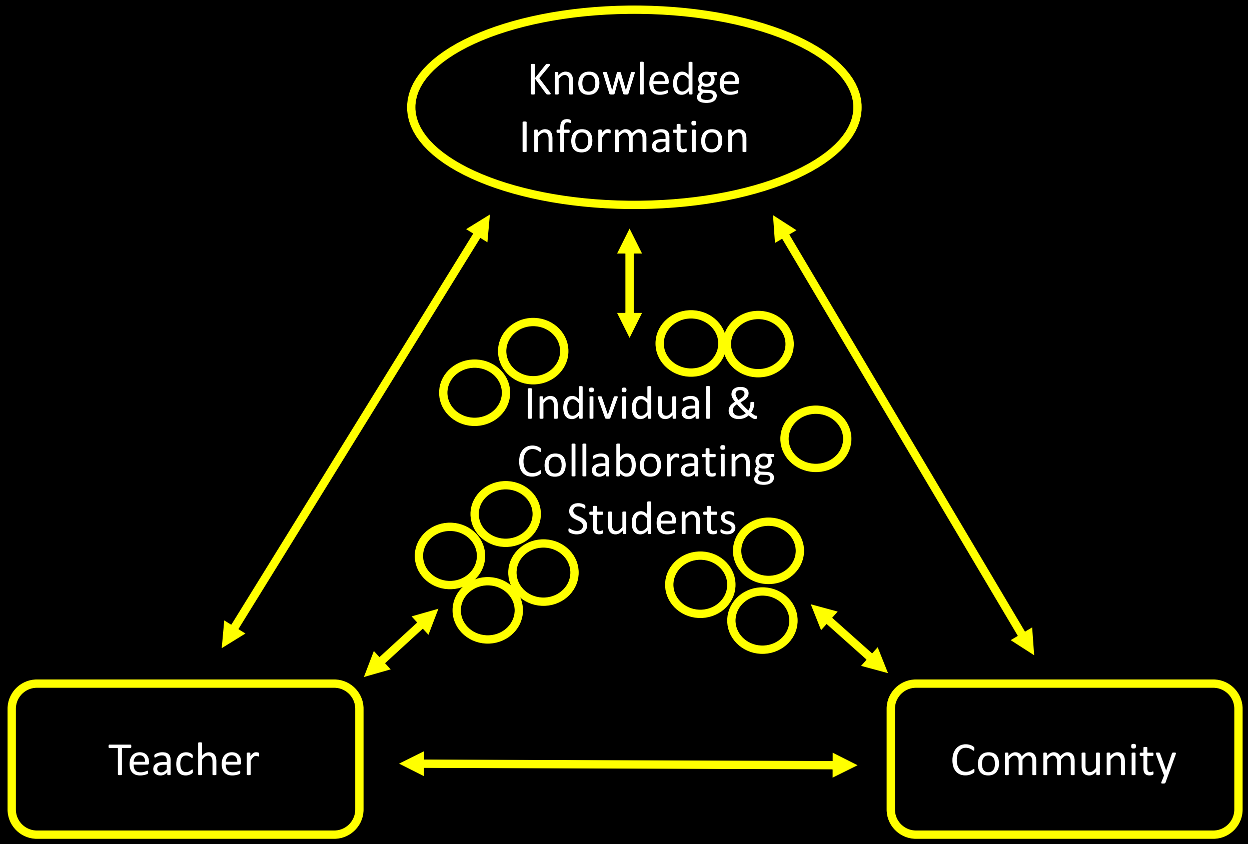
Student-Centered Learning

(Hirumi, 2002)

Active Student-Centered Learning (Tactics)

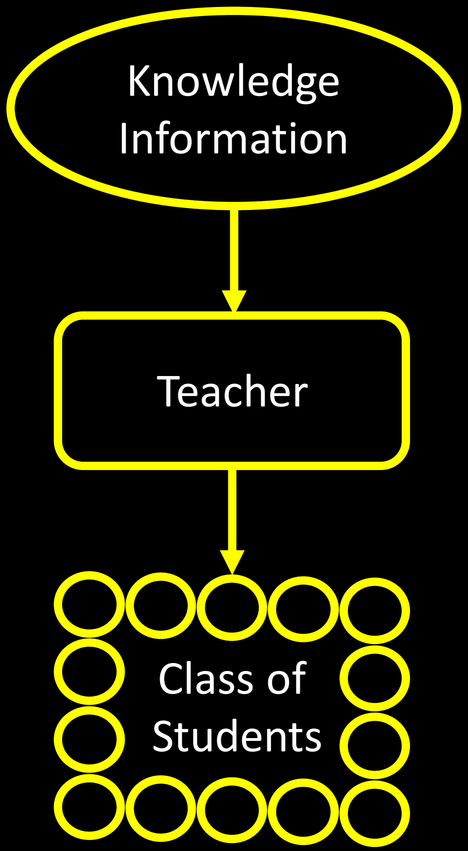


Teacher-Directed Learning

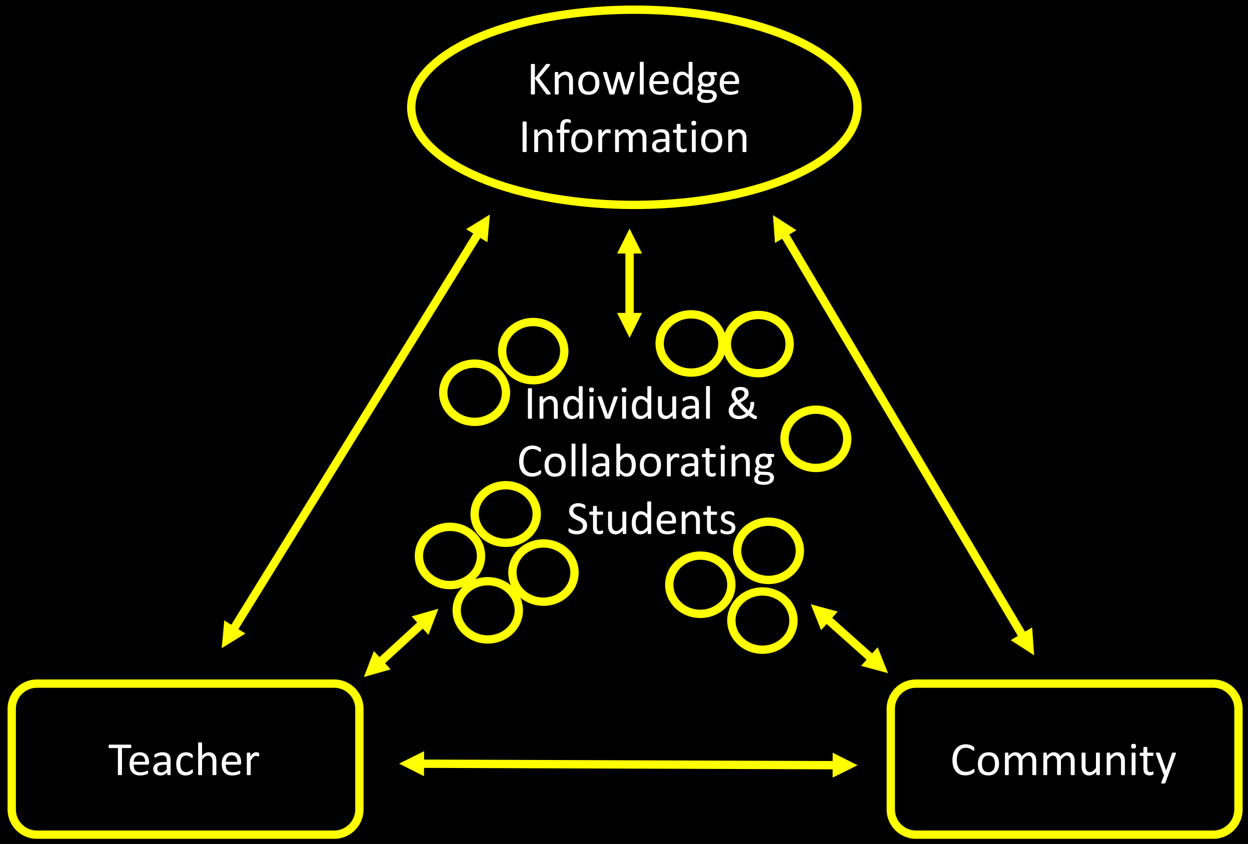


Student-Centered Learning

Active Student-Centered Learning (Strategies)



Teacher-Directed Learning



Student-Centered Learning

Table 3. Sample instructional strategy applying guided experiential learning (Clark, 2004)

Event	Description	Tools
Goals	Asynchronous: Present terminal and enabling objectives Synchronous: Review objectives at start, refer during	• LMS (Modules) • LMS (Conference) • Class
Reasons & Activation	Asynchronous: Ask students to recall problems with misalignment. Activate prior knowledge of objectives Synchronous: Ask students to recall problems with misalignment. Activate prior knowledge of objectives	• LMS (Modules) • LMS (Conference) • Class
Demonstration	Asynchronous: Embed content information on (a) NRT vs. CRT, (b) types of assessment, and (c) forms of assessments within video of expert completing LAAT Synchronous: Demonstrate process for completing a learner assessment alignment table. Provide links to and review content information on NRT vs. CRT, types and forms of assessments.	• LMS (Modules) • LMS (Conference) • Class
Application	Asynchronous: Ask learners to generate individual draft LAATs Synchronous: Ask learners to draft simple LAAT in class, and complete individual assignment online.	• LMS (Modules) • LMS (Discussion) • LMS (Conference) • Class
Integration	Asynchronous: Learners to complete LAAT as team for course project. Post to receive feedback. Synchronous: Learners may work with teammates in class time permitting	• LMS (Modules) • LMS (Discussion) • LMS (Conference) • Class
Assessment	Asynchronous: Use assessment rubric to provide feedback on drafts as well as to provide feedback and evaluate final copy. Synchronous: Use assessment rubric to provide feedback on drafts	• LMS (Modules) • LMS (Discussion) • LMS (Conference) • Class

Overview

You will encounter these interactive elements in the following cases.
They will either provide you with useful information or help you progress with the case.

Question: What should you say?

Yes **No**

Choose the correct answer
to continue the case.

New studies about COVID-19 are being published frequently, and the best strategies will likely evolve.

This case illustrates the best known practices for COVID-19 patients at the time of publication.

Medical glossary

Specific information

Additional information

Previous slide

Next slide

ARDS

Back

Start the case

Case Selection

Early Symptomatic Management

Lead author: Julie Rice, MD, MSMS
Co-Authors: Eisha Chopra, MD, Julianna Jung, MD, Daniel Swedien, MD

Worsening dyspnea in patients with suspected or confirmed COVID-19 infection is concerning for progressing pulmonary disease. These patients warrant further inpatient evaluation and management. In this case, you'll gain an overview of supportive care measures for symptomatic patients and infection control interventions necessary to reduce COVID-19 transmission.

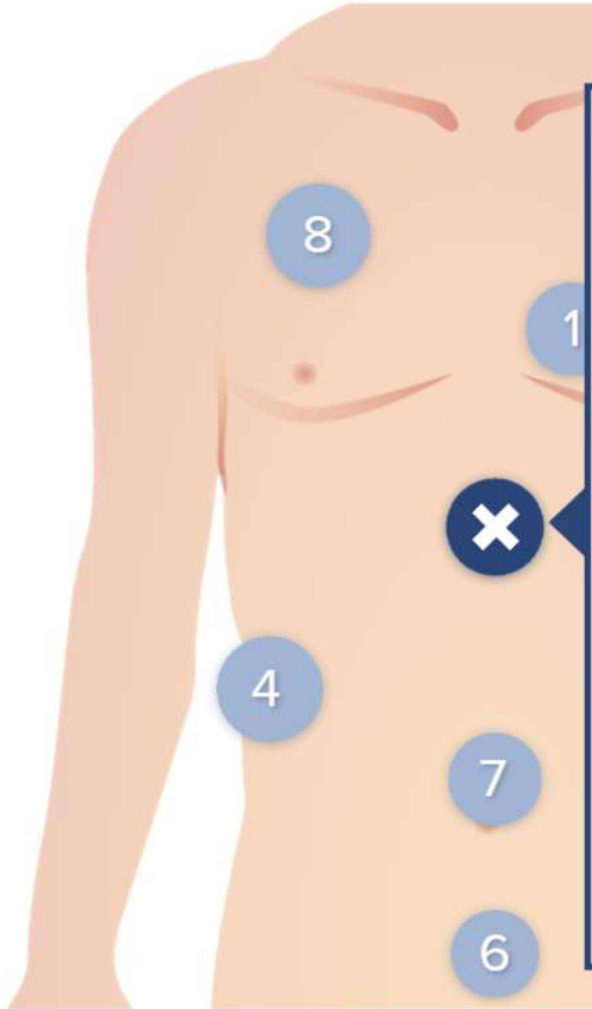
The learning objectives for this case are:

- Choose correct PPE for providers caring for COVID-19-positive patients.
- Apply initial management steps for symptomatic COVID-19-positive patients that minimize aerosolization.
- Describe why non-invasive ventilation (NIV) is avoided in COVID-19-positive patients.
- Recall goal oxygenation targets for symptomatic/hypoxic COVID-19-positive patients.

Start the case

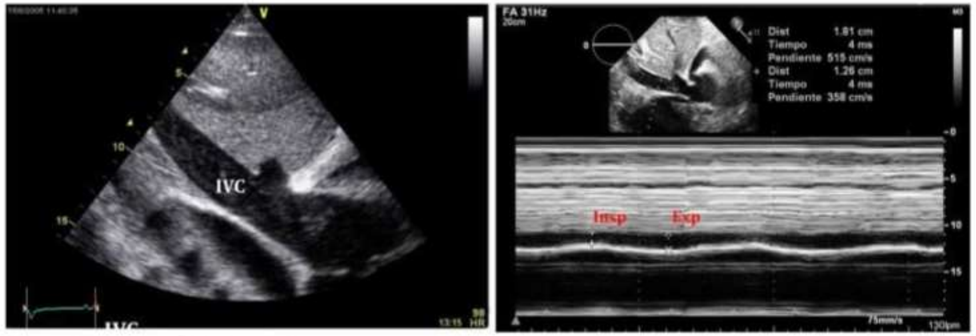
x

RUSH Exam



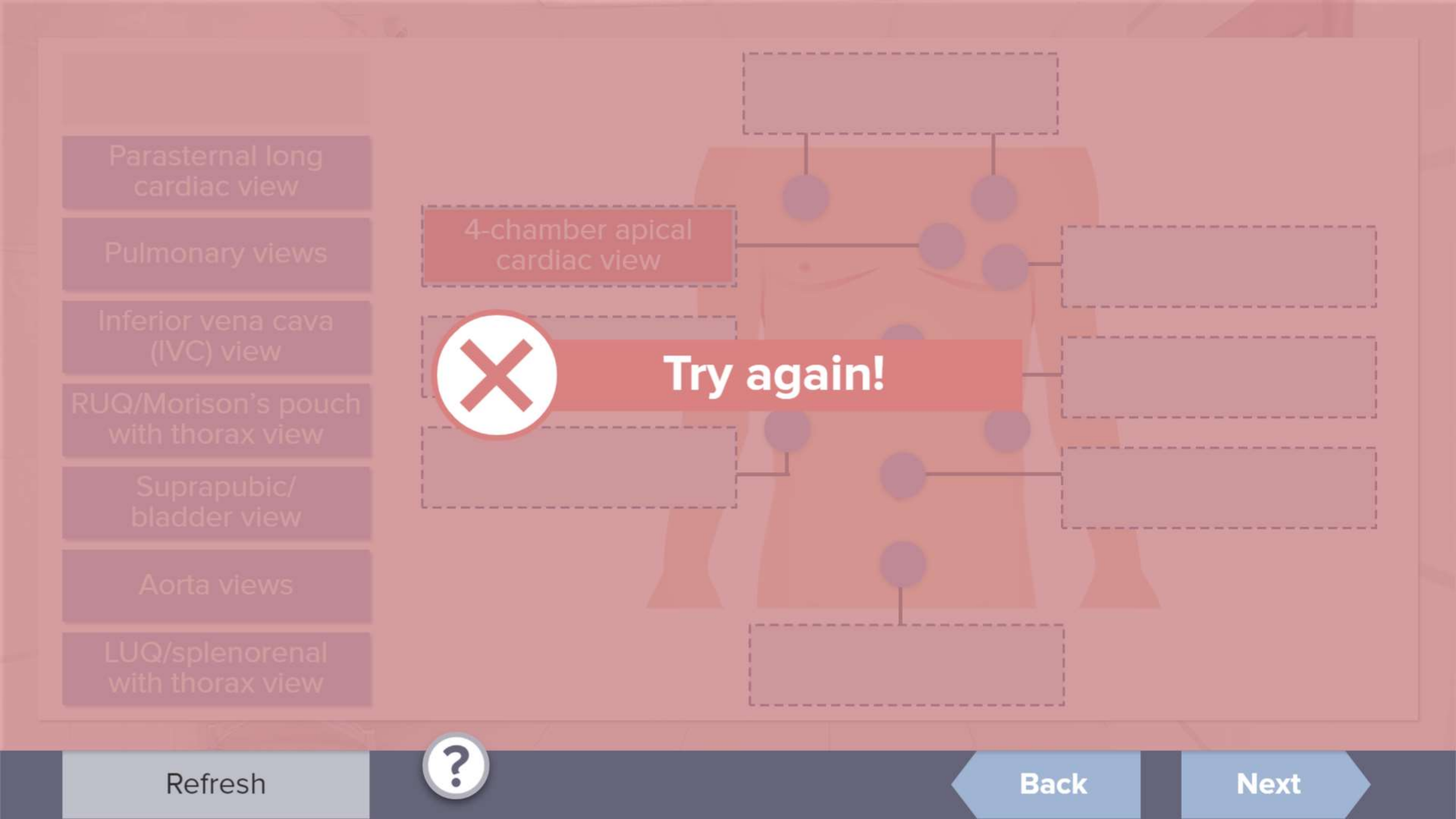
Inferior Vena Cava (IVC) View

- Obtain IVC view with either abdominal or cardiac probe.
- IVC >2 cm in diameter and inspiratory collapse < 50% approximates central venous pressure (CVP) > 10 cmH_2O.
  This is not applicable for intubated patients!



Front Pediatr. 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5401877/figure/F11/, CC BY 4.0, no changes

Back
Next



Parasternal long cardiac view
Pulmonary views
Inferior vena cava (IVC) view
RUQ/Morison's pouch with thorax view
Suprapubic/ bladder view
Aorta views
LUQ/splenorenal with thorax view
4-chamber apical cardiac view
Try again!
Refresh
?
Back
Next

Test yourself 2/2

Choose the right answer.

Why is NIPPV avoided in patients with COVID-19?

- ○ It decreases lung compliance.
- ○ There is no data for mortality reduction.
- ● There is a risk of virus aerosolization.

Great! You managed all the questions right! Select a new case

Go to case selection


16:31
Blood pressure
81 / 54
mmHg
Pulse
146
/min
Breath Rate
38
/min
O2 Sat
79
%
Et CO2
mmHg
Vincent Turner (80.0 Kg)
ECG
II
Vincent Turner (80.0 Kg)
V
5
10
15
Poses
Views
Dialogue
Physical exam
Monitoring
Tests
Call
Interventions
Medication
Medical Records

When do we use teacher-directed vs. learner-centered methods?

Learned Outcomes

Table 2. Comparison of published taxonomies of learning

Tripartite (Hilgard, 1980)	Gagne (1985)	Bloom (1956)	Revised Bloom Anderson & Krathwohl (2001)		Anderson (1981)	Reigeluth & Moore (1999)	Miller (1990)	Krathwohl, Bloom & Masia (1964)	Simpson (1972)
Cognitive	Verbal Information	Knowledge	Factual Knowledge Conceptual Knowledge Procedural Knowledge Meta-Cognitive Knowledge	Remember	Declarative Knowledge	Memorize Information	Knows (Knowledge)		
	Concepts	Comprehension		Understand		Understand Relationships	Knows How (Competence)		
	Procedures & Rules	Application		Apply	Procedural Knowledge	Apply Skills	Shows How (Performance)		
	Problem Solving	Analysis Synthesis Evaluation		Analyze		Apply Generic Skills	Does (Action)		
	Cognitive Strategies			Evaluate					
				Create					
Affective	Attitudes							Receiving Responding Valuing Organization Characterization	
Psychomotor	Motor Skills								Perception Set Guided Response Mechanism Complex Response Adaptation Origination

Learned Outcomes

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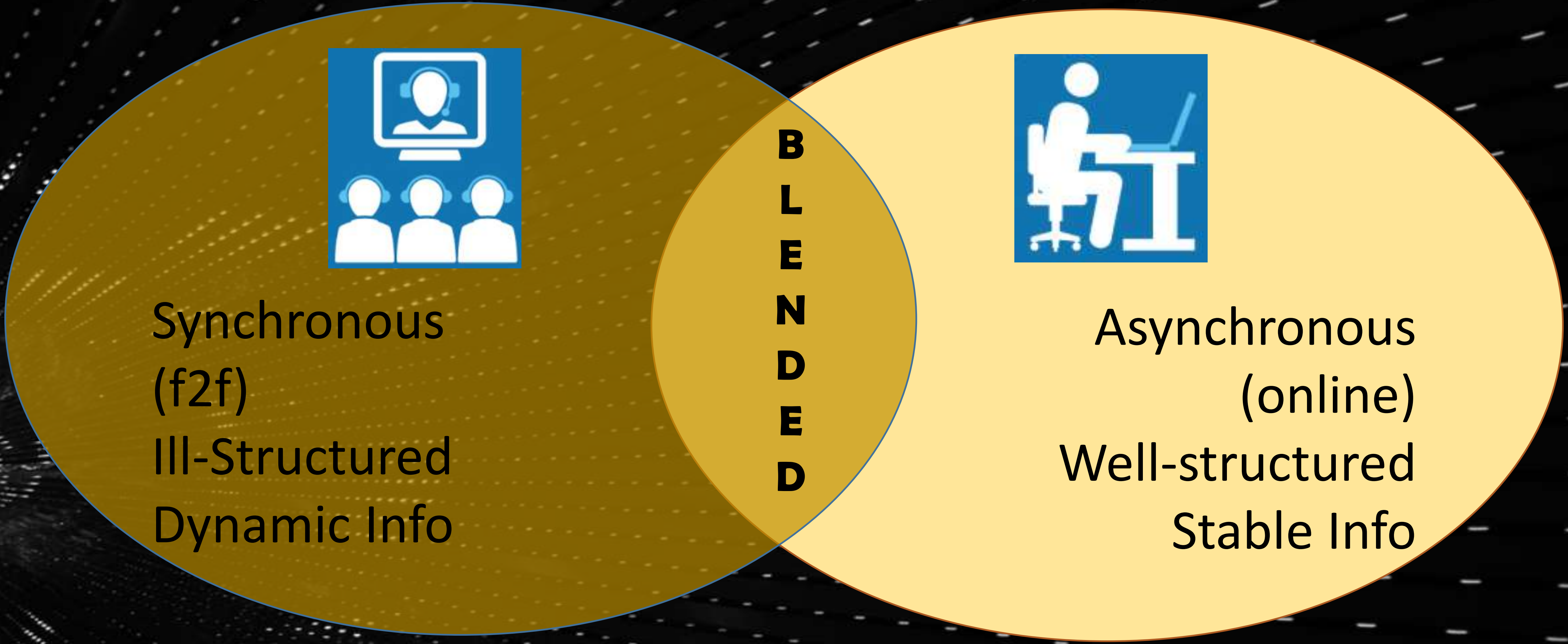
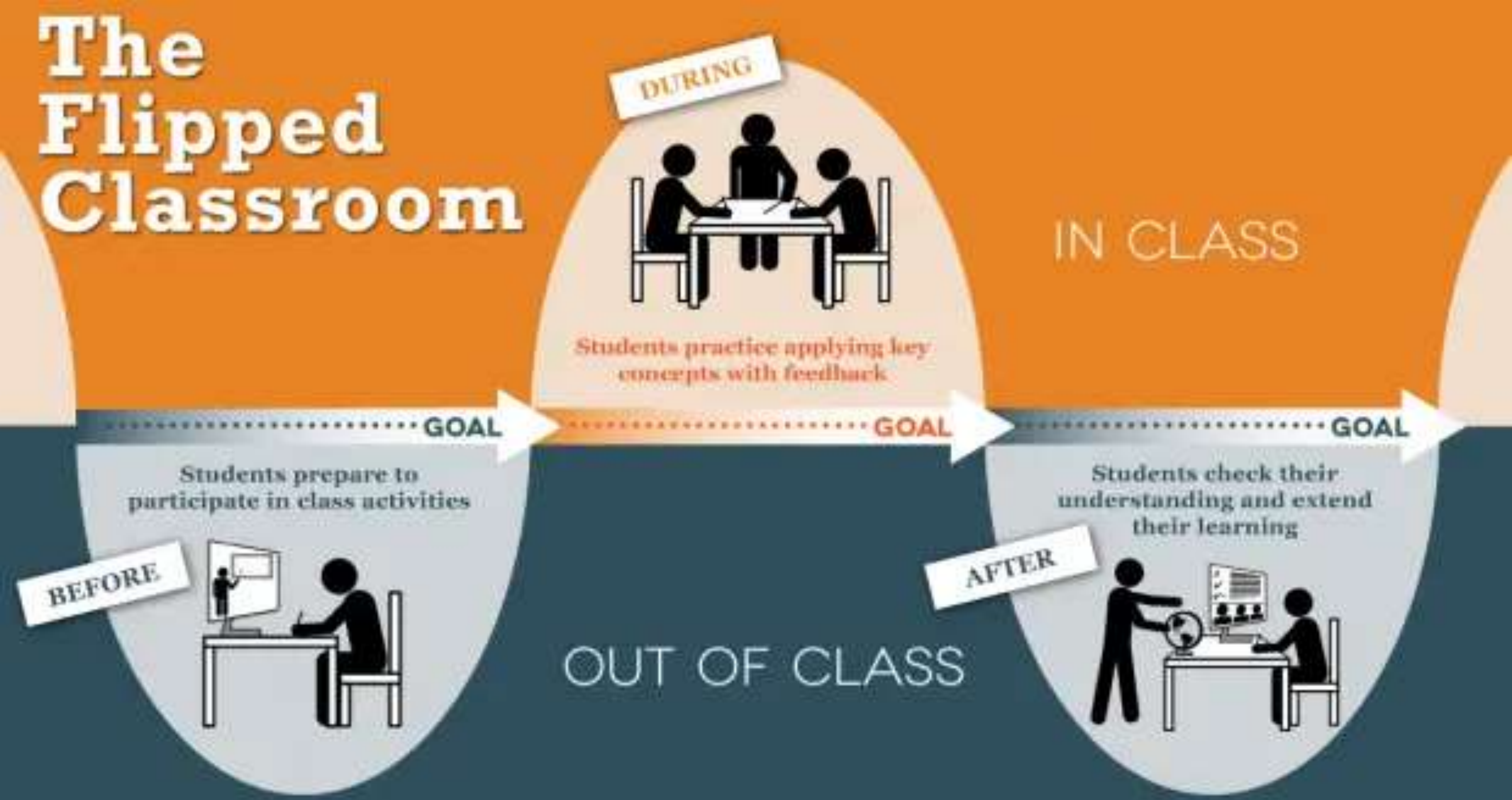
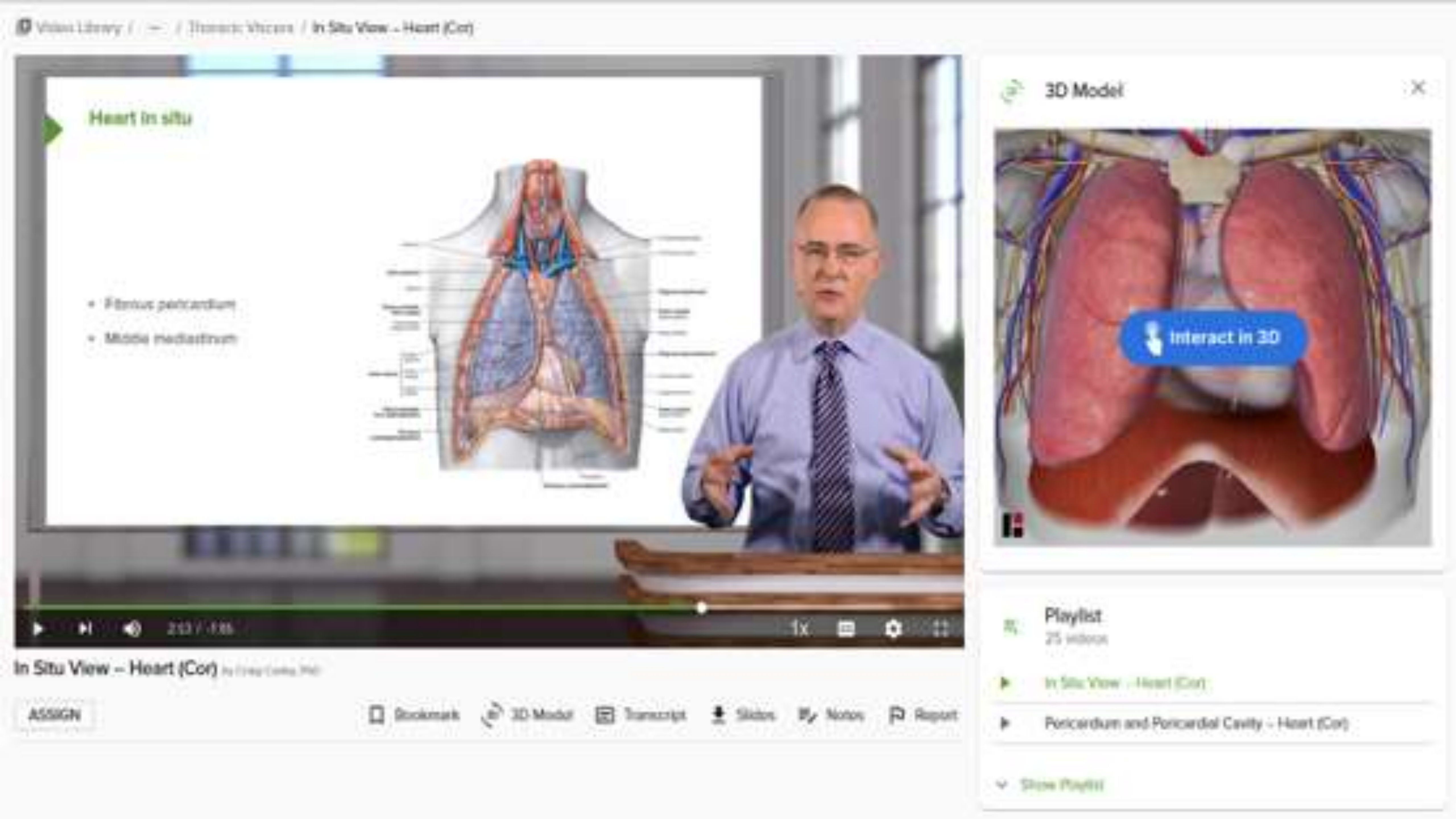
	Concepts	Comprehension		Understand		Understand Relationships	Knows How (Competence)		
	Procedures & Rules	Application		Apply	Procedural Knowledge	Apply Skills	Shows How (Performance)		
	Problem Solving	Analysis Synthesis Evaluation		Analyze		Apply Generic Skills	Does (Action)		
	Cognitive Strategies			Evaluate					
				Create					
Affective	Attitudes							Receiving Responding Valuing Organization Characterization	
Psychomotor	Motor Skills								Perception Set Guided Response Mechanism Complex Response Adaptation Origination

Blended Learning



(Hirumi, Bradford, & Rutherford, 2011)


The Flipped Classroom
DURING
Students practice applying key concepts with feedback
IN CLASS
GOAL
GOAL
GOAL
Students prepare to participate in class activities
Students check their understanding and extend their learning
BEFORE
AFTER
OUT OF CLASS


Video Library / … / Thoracic Viscera / In Situ View – Heart (Cor)
Heart in situ
Fibrous pericardium
Middle mediastinum
1x
In Situ View – Heart (Cor)
ASSIGN
Bookmark
3D Model
Transcript
Slides
Notes
Report
3D Model
Interact in 3D
Playlist
25 videos
In Situ View – Heart (Cor)
Pericardium and Pericardial Cavity – Heart (Cor)
Show Playlist

ADMINISTRATION

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- Content Management
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- Patient Notes (Beta)
- User Management
- Settings

CONTENT VIEW

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User Statistics

Jun 15, 2019 - Jun 15, 2020

Active Users	Started Lectures	Answered Recall Questions	Answered Qbank Questions	Viewed Articles
185	81,809	273,886 61 % correct	10,925 60 % correct	535

Groups | Users

Name	Videos			Recall Questions		Articles	Qbank Questions	
	Started	Finished	Watched Minutes	Answered	% correct	Viewed	Answered	% correct
Admin	150	122	758	53	70 %	14	38	37 %
Clinical Rotations	4,488	4,262	22,601	4,537	84 %	4	2,088	61 %
Faculty Staff	1,056	431	3,324	2,169	75 %	76	1,064	79 %
MD 10	3,236	3,194	15,724	151	75 %	0	1,103	51 %
MD 11	3,280	3,251	15,827	380	72 %	0	870	51 %
MD 12	380	326	2,480	1,376	79 %	1	406	43 %
MD 13	16,075	14,560	86,244	55,742	61 %	32	2,875	66 %
MD 14	6,654	6,309	38,197	10,137	52 %	16	516	55 %
MD 15	29,492	27,830	161,027	97,594	58 %	152	490	43 %
MD 16	8,596	8,233	45,178	38,832	54 %	33	69	30 %

Overview | Performance by Course | Performance by User

Filter by:

Date Range

Last 12 Months

Group

ALL

User

ALL

Course Subject

ALL

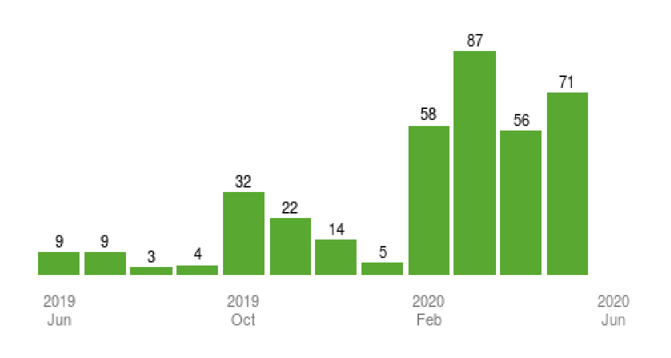
Course

ALL

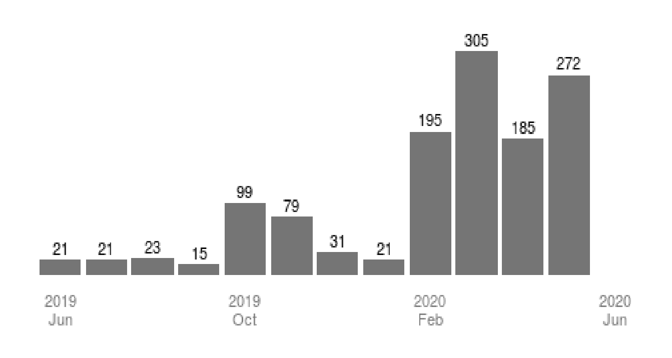
Qbank Question Subject

ALL

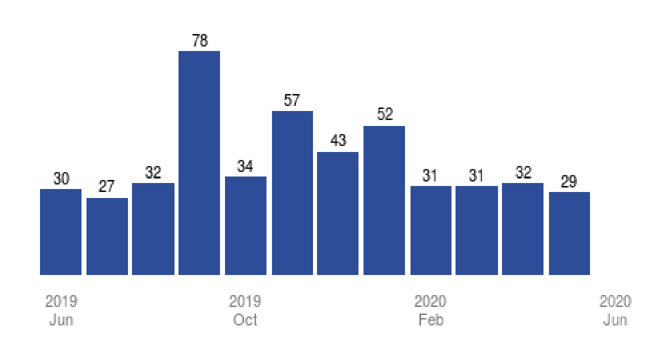
Average Lectures Watched per User



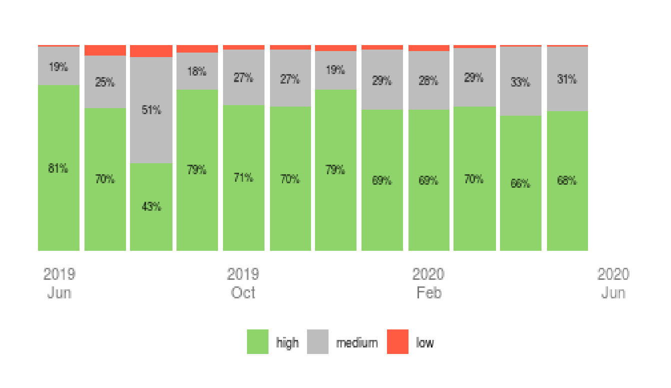
Average Recall Questions Answered per User



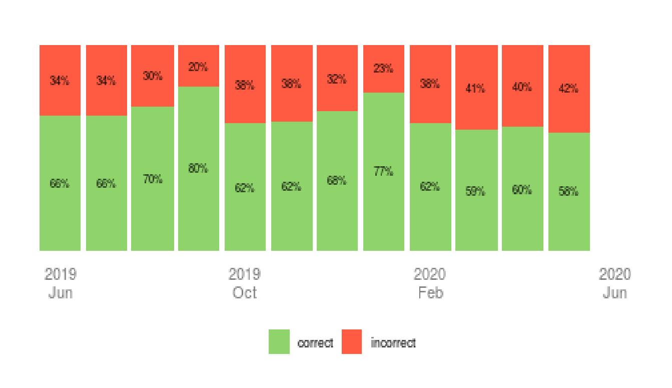
Average Qbank Questions Answered per User



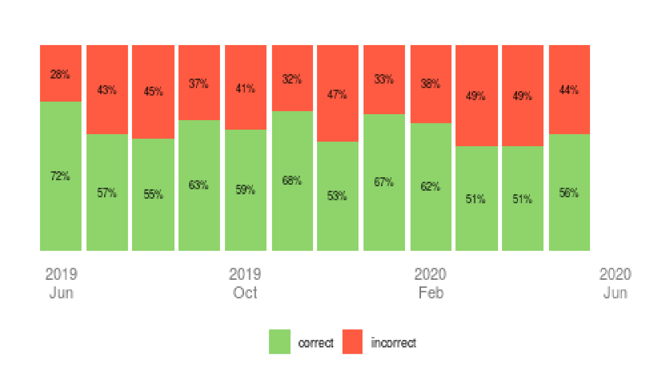
Overall Recall Question Confidence



Overall Recall Question Performance



Overall Qbank Question Performance



Polling questions?

1. To what extent does your school promote active student-centered learning?

2. How many of your faculty use a flipped classroom approach?

3. To what extent do you think medical education should be conducted in a blended or flipped fashion?

COVID 19
What will be its Silver Lining?

Industrial Age Education

↓

21st Century Education

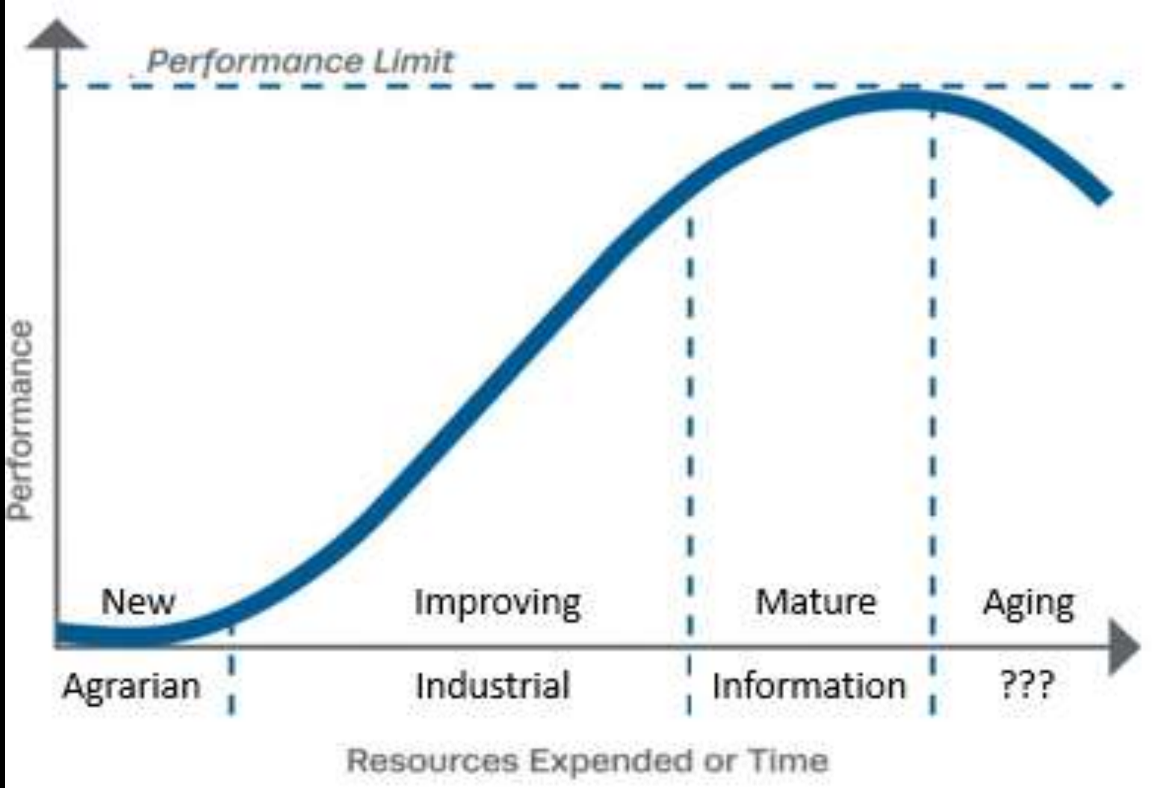


Figure 3. Maturation of educational productivity under industrial age model overtime

Table 4. Comparison of significant changes across sections

Sector	Agrarian	Industrial	Information
Transportation:	Horse	Trains & Cars	Airplanes
Communications:	Mail	Telephone	Computers
Business:	Family	Bureaucracy	Teams
Medicine:	Crafted	Science	Evidence
Education:	One-room Schoolhouse	Conventional Schools	???

What changes must be made to current medical education system to meet healthcare needs of 21st century?

Transformation of the Educational Process

Platform-based learning: The new gold standard

- Flipped classroom - apply evidence-based learning strategies- no live lectures!
- Move from passive to interactive learning- game learning
- Teachers as coaches, mentors, and motivators; creators of content
- Person-to-person interaction augmented, not diminished
- Cost effectiveness in education (Reusing Learning Objects)

Transformation of the Educational Process

- Lock step progression → Mastery-directed learning
- Historical precedent → Data-driven teaching and learning
- Testing to assign rank → Testing as a diagnostic and learning tool
- New predictors of performance – grit, perseverance, creativity

Unprecedented Advantages

What does the future hold?

- Mastery directed learning
- Teaching and learning beyond University walls- Platform becomes the new campus
- Continuing education – involve alumni-perpetual community
- Wiki authoring-teachers as editors
- Tuition reduction- shared educational resources
- Vastly improved access

Intelligent (Big) Data Analytics

Police – Arrest patterns mapped to events (holidays, paydays, traffic flow, rainfall, etc.) to detect and prevent crimes.

Business – Mouse clicks mapped to purchasing patterns and customer satisfaction to customize web pages and increase sales.

Hospitals – Patient data mapped to diagnoses and outcomes to facilitate prevention, diagnosis, management, and reduce readmissions.

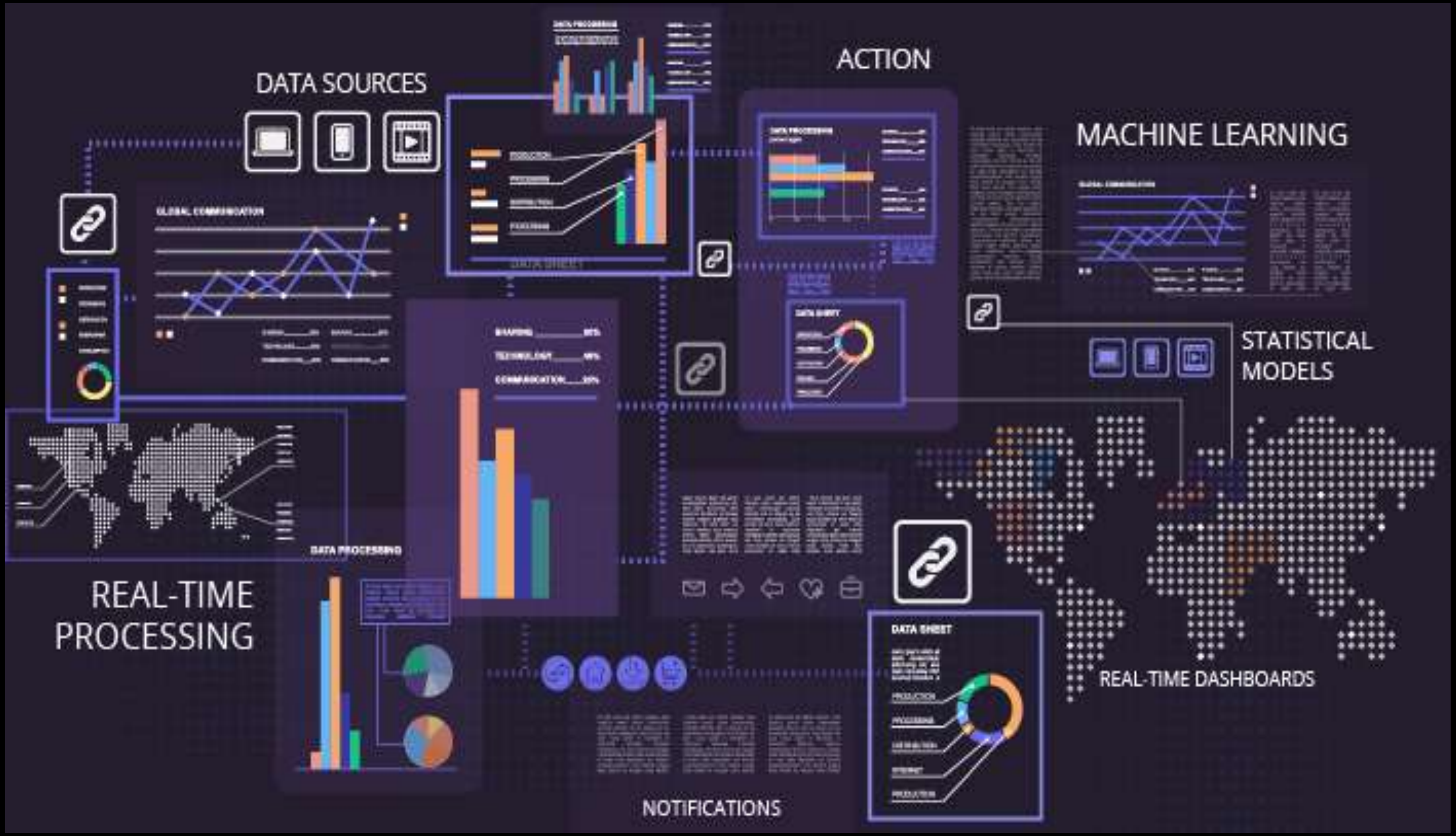


Figure 5. Intelligent big data analytics architecture
https://www.scnsoft.com/blog/real-time-big-data-analytics-comprehensive-guide

Performance Ecosystem

Ecosystem – A network of interactions between organisms and their environment.
Software Ecosystem – A set of software solutions that enable, support, and automate transactions by users within a business ecosystem.
Learning Ecosystem – A learning community supported by a foundation of interacting organizations and individuals.
Performance Ecosystem –Integrated applications that enhance individual and organizational effectiveness and efficiency by connecting people with each other and with data, processes, and technologies that drive performance.

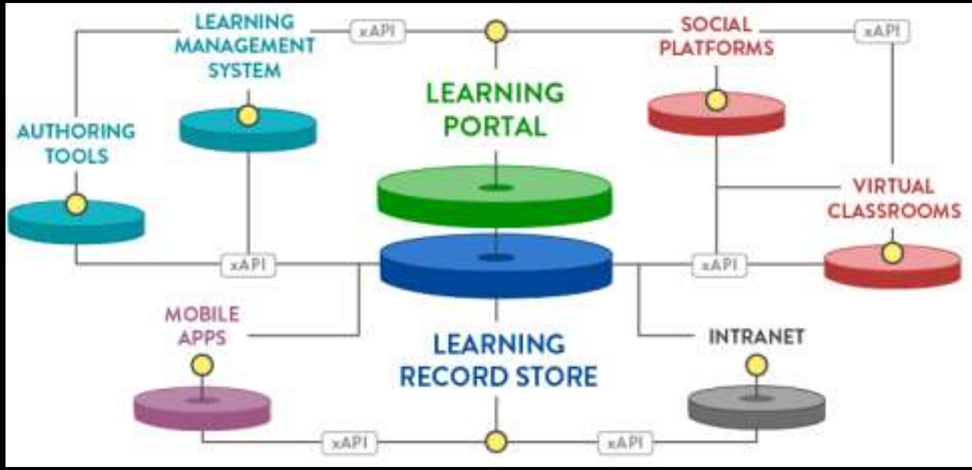


Figure 6. Learning Software Architecture
http://www.sproutlabs.com.au/blog/learning-technologies-for-learning-while-working/

Figure 7. Performance Ecosystem
https://learningsolutionsmag.com/articles/1568/marc-my-words-in-learning-and-performance-ecosystems-part-2

Adaptive Competency-Based Learning

Variables	Industrial Age Model	Competency-Based Model
TIME	Constant (Faculty-Paced)	Variable (Self-Paced)
ACHIEVEMENT	Varies (Bell Curve)	Constant (Mastery)
STRUCTURE	Cohort (Courses)	Individuals (Modules)
ASSESSMENT	Certify & Rank (High Stakes MCQs)	Facilitate Learning (Portfolios)
OUTCOMES	Discrete (SKDs)	Competencies (EPAs)
INSTRUCTION	Teacher-Directed (average learner)	Student-Centered (individual learners)

Adaptive Competency-Based Learning

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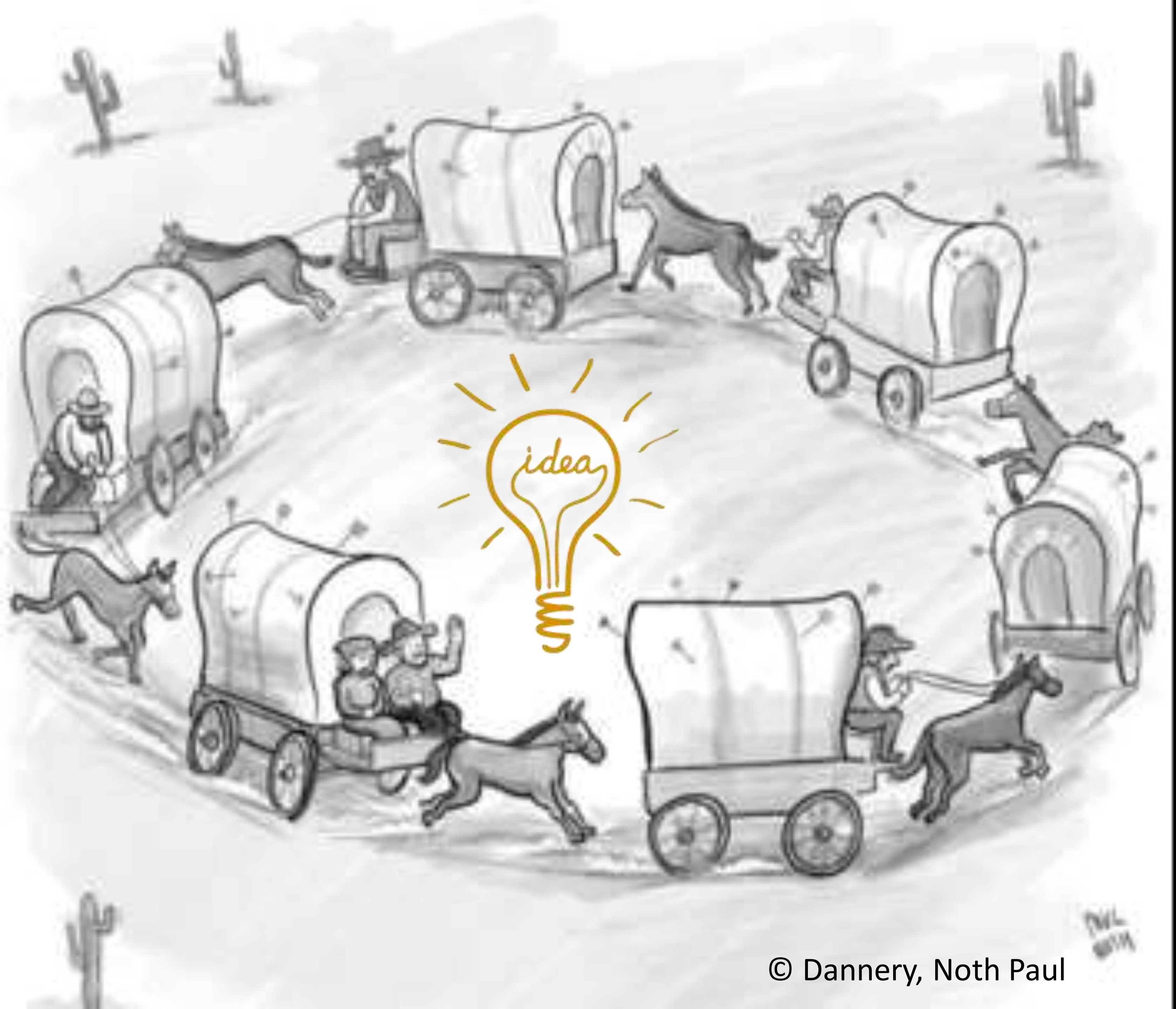
INSTRUCTION	Teacher-Directed (average learner)		Student-Centered (individual learners)

How do we get faculty to flip courses, facilitate active, student-centered learning, and meet the needs of 21st century?

Characteristics affecting adoption

- **Relative Advantage** - Better than the idea, practice, or object it supersedes (time, money or status).
- **Compatibility** – Consistent with existing values, past experiences, and needs of potential adopters.
- **Complexity** - Relatively difficult to understand or use.
- **Triability** - Experimented with on a limited basis. Directly related to immediate and reoccurring costs.
- **Modifiability** – Modified to meet unique individual and contextual needs.
- **Observability** - Results of an innovation are visible to others.

(Rogers, 2003)



- Protect innovation and innovators
- Enable small successes
- Build infrastructure and align system to support change overtime

Summary

Table 1. Comparison of EBME with EBM Correlates

EBM	EBME
1. Articulate Patient's Needs	Assess Educational Needs
2. Ask Questions	Ask Questions
3. Acquire & Appraise Evidence	Acquire & Appraise Evidence
4. Apply Evidence	Apply Evidence
5. Assess Evidence	Assess Evidence

Summary

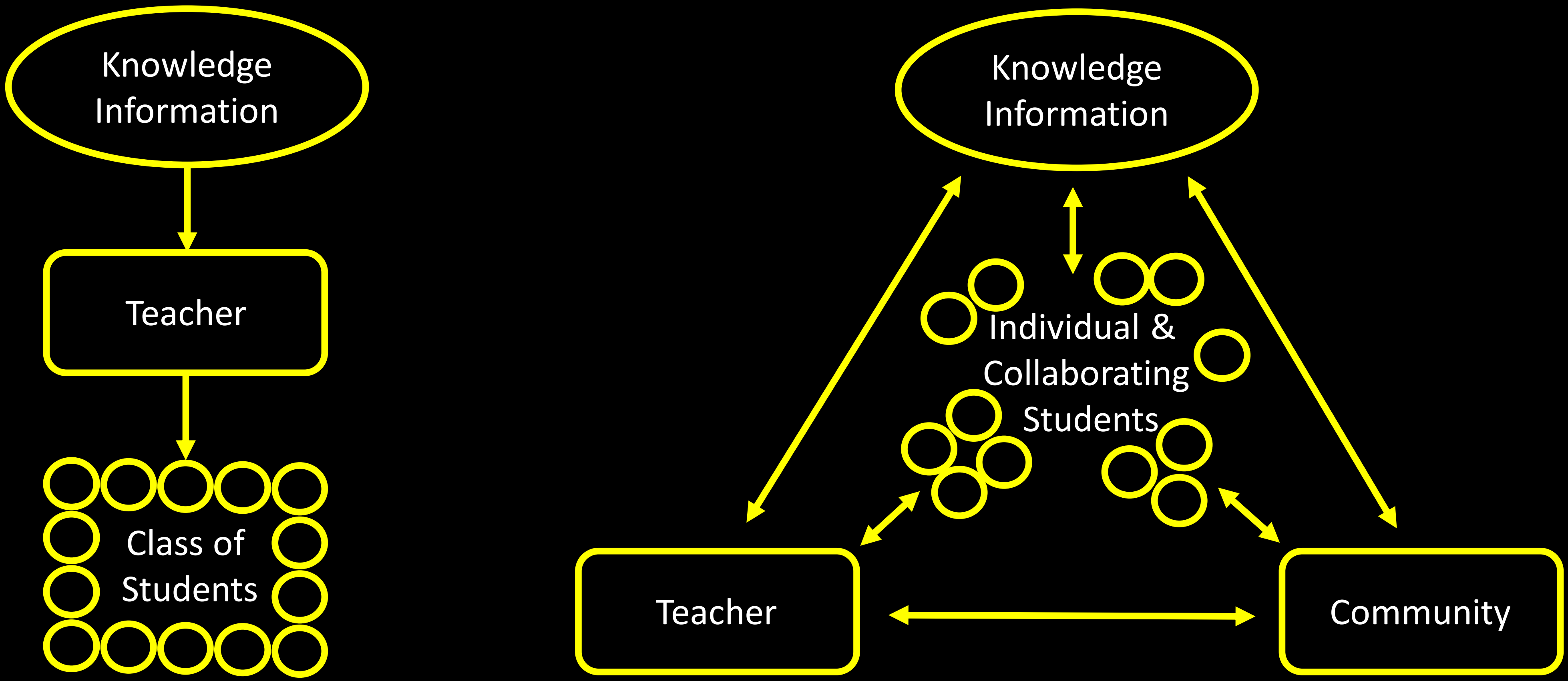
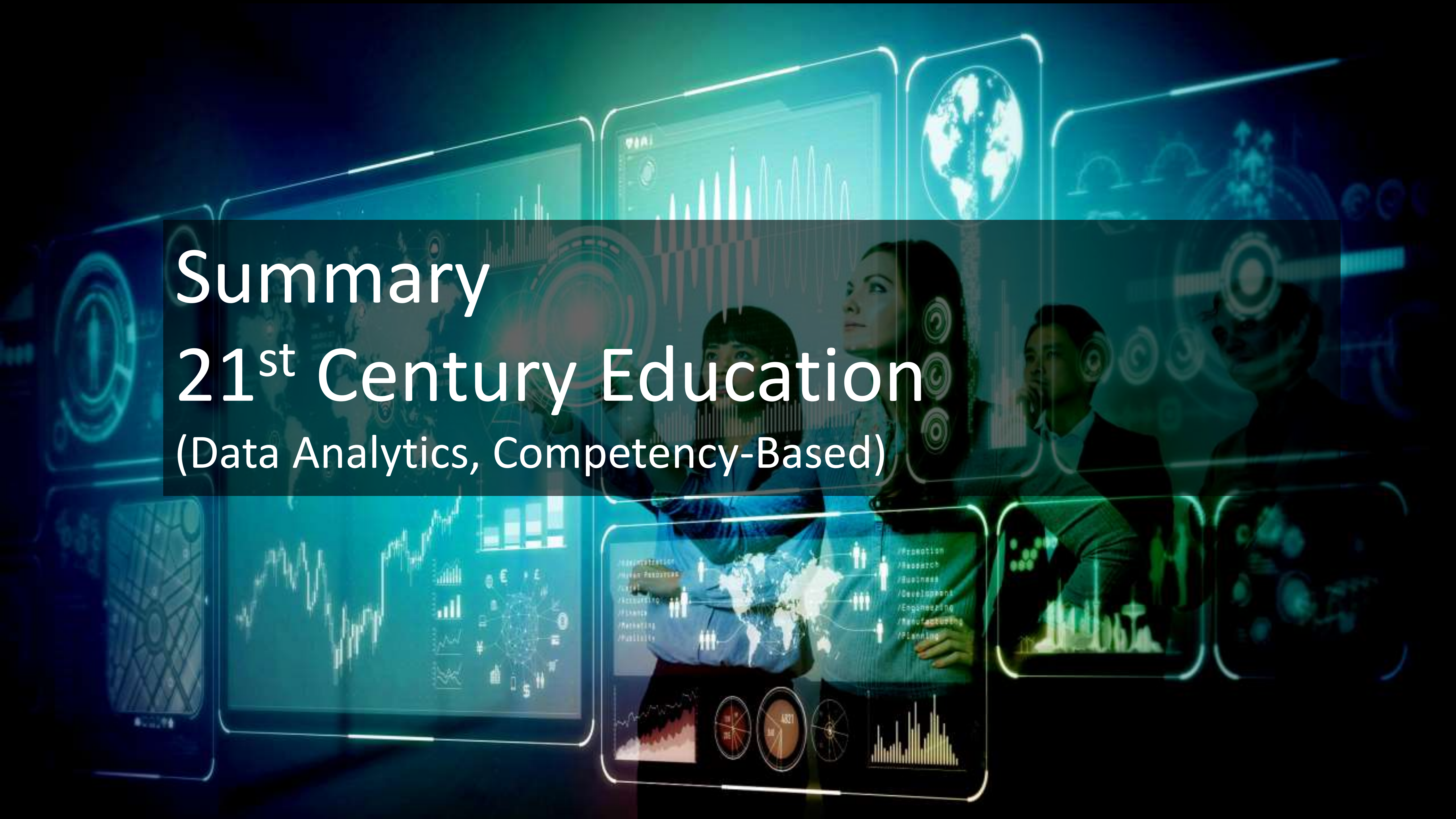


Figure 1. Comparison of Teacher-Directed Learning vs. Student-Centered Learning (Hirumi 2002)



Summary
21st Century Education
(Data Analytics, Competency-Based)

Reflections:

What do you think medical education should look like in 5-10 years?

1. Based on what you are doing now, what would you like to…
   A. Keep?
   B. Modify?
   C. Eliminate completely?
2. What new approaches would you like to try?
3. What barriers are keeping you from trying those approaches?

Reflections:

What will YOU do to change the way medicine is taught?

If YOU don’t, someone else will…

Let us know how we can help!

Please send us your suggestions

peter.horneffer@lecturio.com | Atsusi.Hirumi@ucf.edu

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The application of evidence that underpins best practice raises three fundamental questions: (1) What is the evidence? (2) How does one select/evaluate the evidence? and, (3) How does one apply the evidence? We present a multi-part series to help educators and educational specialists organize and apply the plethora of related research and theory that may be used to practice evidenced-based medical education (EBME) starting with three DOMAINS of evidence. Distinguishing the domains helps answer Question 1. Guidelines from one published resource is included to characterize each domain. A bibliography of sample studies is provided separately to further distinguish the domains.

Domain 1. Learning Outcomes. Research and theory on achieving specified learning outcomes suggest that the design instruction should be based on what you want students to learn. Understanding outcomes serves as a starting point for guiding evidence-based educational practices.

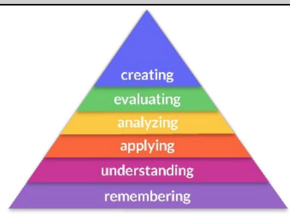

Figure 1. Updated Bloom's taxonomy of learning outcomes[1]

Applying Procedural Knowledge[2]

- Learn to *determine if/when procedure is required*. Provide correct answer feedback with learner controlled explanatory feedback.
- Learn to *list the steps in a procedure*.
- Learn to *complete the steps in a procedure*.
- Learn to *elaborate sequence*, starting with simple epitome of rule and elaborating to more complex versions of same rule.
- Learn to *check appropriateness of completed procedure*.

Domain 2. Learning Theories. Five major classes of theories have evolved over time to explain and predict human learning. The use of learning theories to guide EBME suggests that the underlying principles that govern how and why people learn transcend research and theory on desired learning outcomes and instructional approaches.

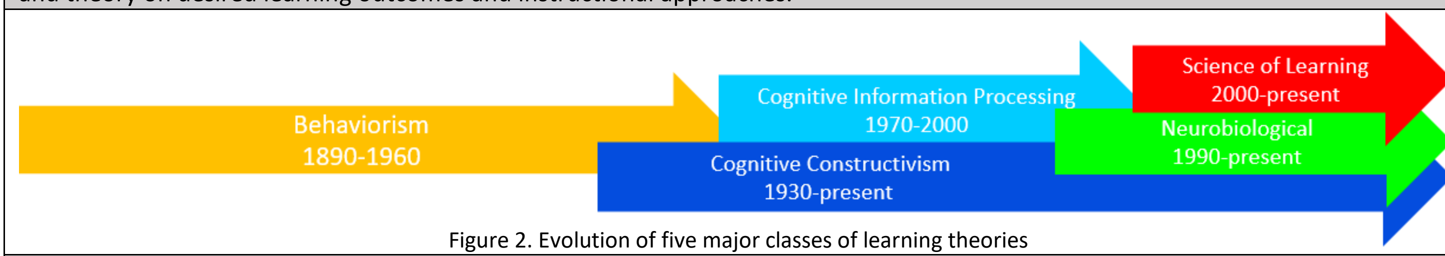

Figure 2. Evolution of five major classes of learning theories

Make it Stick: The Science of Successful Learning[3]

1. *Practice retrieval* by recalling facts and events to monitor progress, spot gaps, and adapt instruction to correct misconceptions.
2. *Space practice* to require the reconstruction of memory that reinforces meaning and promotes learning.
3. *Interleave practice* by mixing problem types, requirements, and procedures to engage different parts of the brain.
4. *Elaborating on* new information adds meaning by expressing ideas in personal terms and connecting it with what is already known.
5. *Reflection on learning* to retrieve memories, connect prior knowledge, and visualize behavior to promote mental rehearsal.
6. *Generate solutions* using prior knowledge and creativity to form and test answers, and learn from authentic experiences.
7. *Calibrate learning* to avoid illusions of mastery by assessing, and if necessary, remediating new and prior knowledge.
8. *Embrace difficulties* to broaden mastery by interleaving practice at different times, in different context, with different materials.
9. *Avoid undesirable difficulties* that can create anxiety, an aversion to risk-taking, and feelings of incompetence.
10. *Use and formulate mnemonics* to hold information in memory by using visualization and mental images to cue memories.

Domain 3. Instructional Approaches. Research and theory on different approaches to teaching and learning emphasize either the methods or the means used to facilitate learning. Methods may be teacher-directed or student-centered in nature, including but not limited to self, experiential, game-based, or active learning strategies. Means include, but are not limited to the use of conventional classrooms, simulations, online learning, blended learning, and virtual, mixed or augmented reality.

Figure 3. Figure 4. Simulation with VR goggles

Features and uses of high-fidelity medical simulations that lead to effective learning[4]

- *Feedback.* Knowledge of results of one's performance.
- *Repetitive practice.* Opportunity for learners to engage in focused, repetitive practice.
- *Curriculum integration.* Explicit strategy for integrating into medical school curriculum.
- *Range of difficulty level.* Engage in practice of medical skills across a wide range of difficulty levels.
- *Multiple learning strategies.* Large group with instructor, small-group with or without, or independent.
- *Capture clinical variation.* Expose learners to low frequency, high stakes patient problems.
- *Controlled environment.* Make, detect, and correct patient care errors without adverse consequences.
- *Individualized learning.* Adapt content and rate to individual learning needs.
- *Defined outcomes or benchmarks.* With tangible, objective measures defined at appropriate level.
- *Simulator validity.* Degree of fidelity provided to approximate situation, principles, and tasks.

An Illustrative Bibliography of Evidenced-Based Learning Resources

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Domain 3 – Instructional Approaches

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Instructional Design Principles

Instructional design (ID) principles are rules that govern the methods and materials prescribed to facilitate human learning. Such principles may be used by educators and instructional designers to ground the design of training, education, and professional development on research and theory related to human learning, and to direct evidence-based practice. Instructional principles may also be used by organizations to set design standards, specify design requirements, and establish guidelines for large scale instructional design initiatives. Published ID principles are compiled to help educators and designers compare and contrast belief systems and to make informed design decisions.

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Behavioral Design Principles
(Reeves & Reeves, 2015)

In the early to mid-1900's, scientists recognized that learning occurred inside the brain, but since they could neither see nor measure such internal processes, they relied on observations of overt behaviors to explain and predict human learning. Behaviorists' viewed learning as a change in behavior that could be explained by external factors and behavioral conditioning. Interest in behaviorism peaked between 1955 to 1965 with the development of analog teaching machines and programmed instruction (Lumsdaine & Glaser, 1960, as cited in Reeves & Reeves, 2015). Behaviorists argued that operant conditioning and other principles related to reinforcement could be used to teach students in varied educational settings (Reiser 2001).

Instructional design principles derived from behaviorist learning theory include:

- Active learner participation in responding to instructional stimuli is much more effective than passive observation of instruction.
- Behaviors that are rewarded are more likely to be repeated than behaviors that are ignored.
- Immediate reinforcement is more effective in most cases than delayed reinforcement.
- Intermittent reinforcement is more effective than constant reinforcement. – Extinction, i.e., withholding reinforcement of a behavior or ignoring it can result in the decrease of that behavior.
- Extensivepracticewithpositivereinforcementisapowerfulmethodfordeveloping fine motor skills such as playing a piano or injecting a vaccine.
- Information should be presented in small amounts so that responses to questions about the information can be reinforced frequently.

(Reeves & Reeves, 2015, p. 468-469)

Cognitive Information Processing Design Principle

(Reeves & Reeves, 2015)

By the mid to late 1900's, psychologists reasoned that we could no longer ignore what was happening in brain to explain complex forms of learning, and began to formulate cognitive theories of human learning. In addition to observations, cognitive theories explain learning based on paper and pencil tests that measure internal psychological constructs, such as intrinsic and extrinsic motivation (Schunk, Meece, & Pintrich, 2013), Cognitive information processing (CIP) theories relate human learning to functions of computers in which different types of memory, such short-term, long-term and working memory (Anderson, 2000). CIP theories are especially popular among cognitive and computer scientists involved in developing intelligent tutoring systems and other applications of artificial intelligence to promote learning (VanLehn, 2011, as cited in Reeves & Reeves, 2015).

Instructional design principles derived from cognitive information processing learning theory include:

- Working (short-term) memory has inherent limitations that place a cognitive load on learning processes that must be carefully managed during instruction. Instruction should be designed to minimize the cognitive load of extraneous factors (e.g., the user interface of a computer program) and maximize the cognitive capacity to process information needed for learning.

- There are two separate channels that humans use for processing information during instruction, the auditory and visual, and thus, instruction should provide verbal and graphical information in ways that clearly guide the learners to identify and process relevant words and images.

- Learning occurs when humans identify, filter, select, link, organize, and integrate information under the guidance of a tutor, which may be human or computer-based.

- Content to be learned should be organized from simple to complex.

(Reeves & Reeves, 2015, p. 469-470)

Universal Principles of Experiential Learning
(Lindsey & Berger, 2009)

Experiential approaches to teaching and learning are based on two central principles originally posited by Dewey in 1920's and 30's: (a) continuity (the idea that students learned from their experiences), and (b) interaction (the notion that students' experiences were derived from their interactions with the environment and other individuals) (Dewey, 1938, p. 25). Experiential learning is also grounded in the belief that children, adolescents and adults learn best when presented with relevant, meaningful and interesting goals, and foster skill development and the learning of facts, concepts, procedures, and principles in context of how they will be used.

The merits of experiential learning have resulted in a number of recent models, including, but not limited to those posited by Kolb (Kolb, 1984; Kolb & Fry, 1975), Schank, Berman and Macpherson (1999) and Clark (2004). With the plethora of interpretations, Lindsey and Berger (2009) synthesized published approaches, identifying four central tenets of experiential learning to guide research and practice (i.e., learning should be student-centered rather than teacher-directed, focus on real-world experiences, include a high degree of self-direction for decision-making, and consist of feedback regarding the decisions made by the student) and three universal and sequential principles of experiential learning.

Principle 1 - Frame the Experience. The first phase includes communicating the instructional objectives, assessment criteria, expected behaviors, and social structure (with peers, instructors and the environment beyond the class). Variable methods such as didactic instruction may also occur in this phase to provide the foundational knowledge required to successfully engage in and interpret the experience.

Principle 2 - Activate Experience. Activating prior as well as newly initiated experiences are necessary. There are multiple methods for activating experience ranging from laboratory practice to simulations. Key characteristics of activating experience include: (a) providing an authentic experience to facilitate transfer; (b) making decisions that have authentic outcomes; (c) problem orientation so learners clearly perceive and accept the relevance of the specific learning activities in relation to the larger talk problem; and (d) present optimal difficulty to challenge the student but not so difficult that the student does not have a reasonable expectation for success.

Principle 3 - Reflect on Experience. Experience must be analyzed to learn from it. Reflection should involve students answering the questions, "What happened?" "Why did it happen?" "What did I learn?" and "How would I apply this knowledge to future experiences?" Specific methods for stimulating reflection include: (a) teacher facilitation to help learners to identify their beliefs and working with them to master impediments to understanding; and (b) community building which is a part of framing the experience but should be pursued prior to reflecting. A significant element of community building is communicating the equality of the participants and their role in the active critique of others' experience.

Adult Learning Principles
(Knowles, 1970)

1. **Adults tend to be self-directed.** Adults want to participate in the planning and evaluation of their learning.
2. **Adults have rich reservoir of experience.** Adults prefer to build on prior learning and experience.
3. **Adults need to learn experientially.** Adult learn by doing; experiences form bases for knowledge construction.
4. **Adults have problem-solving orientation.** Adults are problem-centered rather than content-oriented
5. **Adults' motivation affected by need to know**. Adults most interested if learning has immediate relevance to job or personal life
6. **Adults motivated by internal/intrinsic factors.** Grades and other extrinsic rewards not as effective with adults.

Adult [Instructional] Design Principles:

1. **Control**. Adults need to be involved in the planning and evaluation of their instruction
2. **Prior Knowledge**. Instruction should stimulate prior knowledge and relate to prior experiences.
3. **Experiential**. Experience (including mistakes) provides the basis for learning activities
4. **Problem-based**. Adult learning is problem-centered rather than content-oriented
5. **Relevance**. Adults are most interested in learning about subjects that have immediate relevance to their job or personal life

Prior Knowledge & Experience (Briefcase):

1. Life experience (including life altering events that affect cognitive abilities)
2. Work experience (including development of thinking patterns based on this experience)
3. Positive/negative previous adult learning experiences
4. Performance affecters, including cognitive abilities
5. Time between learning interactions
6. Aging factors

Learner-Centered Psychological Principles
(APA, 1997)

Cognitive and Metacognitive Factors

1. ***Nature of the learning process.*** The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience.

2. ***Goals of the learning process.*** The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge.

3. ***Construction of knowledge***. The successful learner can link new information with existing knowledge in meaningful ways.

4. ***Strategic thinking.*** The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals.

5. ***Thinking about thinking.*** Higher order strategies for selecting and monitoring mental operations facilitate creative and critical thinking.

6. ***Context of Learning.*** Learning is influenced by environmental factors, including culture, technology, and instructional practices.

7. *Motivational and Affective Factors*

8. ***Motivational and emotional influences on learning.*** What and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states.

9. ***Intrinsic motivation to learn.*** The learner's creativity, higher order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks of optimal novelty and difficulty, relevant to personal interests, and providing for personal choice and control.

10. ***Effects of motivation on effort.*** Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without the learner's motivation to learn, the willingness to exert this effort is unlikely without coercion.

11. Developmental and Social Factors

12. ***Developmental influences on learning**.* As individuals develop, there are different opportunities and constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account.

13. ***Social influences on learning**.* Learning is influenced by social interactions, interpersonal relations, and communication with others.

14. Individual Differences

15. ***Individual differences in learning**.* Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity.

16. ***Learning and diversity**.* Learning is most effective when differences in learners' linguistic, cultural, and social backgrounds are taken into account.

17. ***Standards and assessment**.* Setting appropriately high and challenging standards and assessing the learner as well as learning progress—including diagnostic, process, and outcome assessment—are integral parts of the learning process.

Cognitive Constructivist Teaching Practices and Principles
(Bonk & King, 2009)

1. ***Mind****:* The mind is in the head; hence, the learning should focus on active cognitive reorganization.

2. ***Raw Materials****:* Use raw or primary data sources, manipulatives, and interactive materials.

3. ***Student Autonomy****:* Ask students for personal theories and understandings before any instruction. Allow student thinking to drive lessons and alter instruction based on responses. Place thinking and learning responsibility in students' hands to foster ownership.

4. ***Meaningfulness and Personal Motivation****:* Make learning a personally relevant and meaningful endeavor. Relate learning to practical ideas and personal experiences. Adapt content based on student responses to capitalize on personal interests and motivation.

5. ***Conceptual Organization/Cognitive Framing****:* Organize information around concepts, problems, questions, themes, and interrelationships, while framing activities using thinking- related terminology (e.g., classify, summarize, predict).

6. ***Prior Knowledge and Misconceptions****:* Adapt the cognitive demands of instructional tasks to students' cognitive schemes, while building on prior knowledge. Design lessons to address students' previous misconceptions, for instance, by posing contradictions to original hypotheses and then inviting responses.

7. ***Questioning****:* Promote student inquiry and conjecture with open-ended questions. Also, encourage student question-asking behavior and peer questioning.

8. ***Individual Exploration and Generating Connections****:* Provide time for the selection of instructional materials and the discovery of information, ideas, and relationships. Also, includes encouraging students to generate knowledge connections, metaphors, personal insights, and build their own learning products.

9. ***Self-Regulated Learning****:* Foster opportunity for reflection on skills used to manage and control one's learning. Help students understand and become self-aware of all aspects of one's learning, from planning to learning performance evaluation. Given the focus on individual mental activity, the importance of cooperative learning or peer interaction is in the modeling of and support for new individual metacognitive skill.

10. ***Assessment****:* Focus of assessment is on individual cognitive development within predefined stages. Use of authentic portfolio and performance-based measures with higher order thinking skill evaluation criteria or scoring rubrics.

Social Constructivist Teaching Practices and Principles
(Bonk & King, 2009)

1. ***Mind**:* The mind is located in the social interaction setting and emerges from acculturation into an established community of practice.

2. ***Authentic Problems**:* Learning environments should reflect real-world complexities. Allow students to explore specializations and solve real-world problems as they develop clearer interests and deeper knowledge and skills.

3. ***Team Choice and Common Interest**:* Build not just on individual student prior knowledge, but on common interests and experiences. Make group learning activities relevant, meaningful, and both process and product oriented. Give students choice in learning activities. Foster student and group autonomy, initiative, leadership, and active learning.

4. ***Social Dialogue and Elaboration**:* Use activities with multiple solutions, novelty, uncertainty, and personal interest to promote student-student and student-teacher dialogue, idea sharing and articulation of views. Seek student elaboration on and justification of their responses with discussion, interactive questioning, and group presentations.

5. ***Group Processing and Reflection**:* Encourage team as well as individual reflection and group processing on experiences.

6. ***Teacher Explanations, Support, and Demonstrations**:* Demonstrate problems steps and provide hints, prompts, and cues for successful problem completion. Provide explanations, elaborations, and clarifications where requested.

7. ***Multiple Viewpoints**:* Foster explanations, examples, and multiple ways of understanding a problem or difficult material. Build a broad community of audiences beyond the instructor.

8. ***Collaboration and Negotiation**:* Foster student collaboration and negotiation of meaning, consensus building, joint proposals, prosocial behaviors, conflict resolution, and general social interaction.

9. ***Learning Communities**:* Create a classroom ethos or atmosphere wherein there is joint responsibility for learning, students are experts and have learning ownership, meaning is negotiated, and participation structures are understood and ritualized. Technology and other resource explorations might be used to facilitate idea generation and knowledge building within this community of peers. Interdisciplinary problem-based learning and thematic instruction in incorporated wherever possible.

10. **Assessment**: Focus of assessment is on team as well as individual participation in socially organized practices and interactions. Educational standards are socially negotiated. Embed assessment in authentic, real-world tasks and problems with challenges and options. Focus on collaboration, group processing, teamwork, and sharing of findings. Assessment is continual, less, formal, subjective, collaborative, and cumulative.

Brain-Based (Natural) Learning Principles
(Caine, Caine, McClintic & Klimek, 2005)

Caine and Caine (2007) conclude that "Optimizing the use of the human brain means using the brain's infinite capacity to make connections–and understanding what conditions maximize this process." They identify three interactive and mutually supportive elements that should be present in order for complex learning to occur: "relaxed alertness," "orchestrated immersion," and "active processing."

- An optimal state of mind that we call **relaxed alertness**, consisting of low threat and high challenge.
- The **orchestrated immersion** of the learner in multiple, complex, authentic experience.
- The regular, **active processing** of experience as the basis for making meaning.

By addressing the twelve principles of Brain-Based Learning (BBL), educators and instructional designers create the three conditions necessary for complex learning to occur.

Relaxed Alertness:
1. Principle 11: Complex learning is enhanced by challenge and inhibited by threat associated with helplessness and fatigue.
2. Principle 2: The brain/mind is social.
3. Principle 3: The search for meaning is innate.
4. Principle 5: Emotions are critical to patterning.

Orchestrated Immersion in Complex Experience:
7. Principle 6: The brain/mind processes parts and wholes simultaneously.
8. Principle 1: All learning engages the physiology.
9. Principle 4: The search for meaning occurs through patterning.
10. Principle 10: Learning is developmental.

Active Processing:
11. Principle 9: There are at least two approaches to memory. One is to store or archive isolated facts, skills, and procedures. The other is to simultaneously engage multiple systems in order to make sense of experience.
12. Principle 7: Learning involves both focused attention and peripheral perception.
13. Principle 8: Learning is both conscious and unconscious.
14. Principle 12: Each brain is uniquely organized.

Principles of Brain-Based Learning
(Jensen, 2005)

Several brain-based learning principles drive Jensen's work. Another person might come up with a different list and still be correct. Not everyone agrees on these principles or on the brain-based learning strategies that can be inferred from the principles.

1. **Malleable memories.** Memories are often not encoded at all, encoded poorly, changed ornot retrieved. The result is that students rarely remember what we think they should. Memories are susceptible to inattention, erosion over time, subject bias, misattribution and a host of other confounding conditions. Memories are strengthened by frequency, intensity and practice under varying conditions and contexts.
2. **Non-conscious experience runs automatic behaviors**. The complexity of the human body requires that we automate many behaviors. The more we automate, the less we are aware of them. Most of our behaviors have come from either "undisputed downloads" from our environment or repeated behaviors that have become automatic. This suggests potential problems and opportunities in learning.
3. **Reward and addiction dependency**. Humans have a natural craving for positive feelings, including novelty, fun, reward and personal relationships. There is a natural instinct to limit pain even if it means compromising our integrity. For complex learning to occur, students need to defer gratification and develop the capability to go without an immediate reward.
4. **Attentional Limitations**. Most people cannot pay attention very long, except during flow states, because they cannot hold much information in their short-term memory. It is difficult for people to maintain focus for extended periods of time. We are born with the capacity to orient and fixate attention when it comes to contrast, movement, emotions or survival. But classroom learning requires a level of learned attention and many teachers don't know how to teach this skill. Adapting the content to match the learner provides better attention and motivation to learn.
5. **Brain seeks and creates understanding**. The human brain is a meaning-maker and meaning seeker. We assign value and meaning to many everyday occurrences whether it's on intentional or not. Meaning-making is an important human attribute that allows us to predict and cope with experiences. The more important the meaning, the greater the attention one must pay in order to influence the content of the meaning.
6. **Rough Drafts/Gist Learning**. Brains rarely get complex learning right the first time. Instead they often sacrifice accuracy for simply developing a "rough draft" of the learning material. If, over time, the learning material maintains or increases in its importance and relevance, the brain will upgrade the rough draft to improve meaning and accuracy. To this end, prior knowledge changes how the brain organizes new information. Goal-driven learning proceeds more rapidly than random learning. Learning is enhanced by brain mechanisms with contrasting output and input goals.

7. **Input Limitations.** Several physical structures and processes limit one's ability to take in continuous new learning. The "slow down" mechanisms include the working memory, the synaptic formation time for complex encoding and the hippocampus. While we can expose our brain to a great deal of information in a short time frame, the quality of that exposure is known as "priming" and is not considered in-depth learning. Schools typically try to cram as much content as possible in a day as possible. You can teach faster, but students will just forget faster.
8. **Perception influences our experience**. A person's experience of life is highly subjective. Many studies show how people are easily influenced to change how we see and what we hear, feel, smell and taste. This subjectivity alters experience, which alters perception. When a person changes the way they perceive the world, they alter their experience. It is experience that drives change in the brain.
9. **Malleability/Neural Plasticity**. The brain changes every day and more importantly, we influence those changes. New areas of brain plasticity and overall malleability are regularly discovered. It is known that experience can drive physical changes in the sensory cortex, frontal lobes, temporal lobes, amygdala and hippocampus. In addition whole systems can adapt to experience such as the reward system or stress response system.
10. **Emotional-Physical State Dependency**. Nearly every type of learning includes a "go" or "no go" command to the brain in our neural net signaling process. These complex signals are comprised of excite or suppress signals. Emotions can provide the brain's signals to either move ahead or not. Thus, learning occurs through a complex set of continuous signals which inform your brain about whether to form a memory or not. Both emotional and bodily states influence our attention, memory, learning, meaning and behavior through these signaling systems.

Brain Rules
(Medina, 2014)

In Brain Rules, Dr. John Medina, a molecular biologist, shares his lifelong interest in how the brain sciences might influence the way we teach adults and children, and the way we work. He describes 12 brain rules: What scientists know about how our brains work.

1. **Survival:** The human brain evolved. The brain is a survival organ. It is designed to solve problems related to surviving in an unstable outdoor environment. The strongest brains survive, not the strongest bodies
2. **Exercise:** Exercise boosts brain power. The human brain evolved under conditions of almost constant motion. From this, one might predict that the optimal environment for processing information would include motion..
3. **Sleep:** Sleep well, think well. When we're asleep, the brain is not resting at all. It is almost unbelievably active! Loss of sleep hurts attention, executive function, working memory, mood, quantitative skills, logical reasoning, and even motor dexterity.
4. **Stress:** Stressed brains don't learn the same way. Your brain is built to deal with stress that lasts about 30 seconds. The brain is not designed for long term stress when you feel like you have no control. You can actually watch the brain shrink.
5. **Wiring:** Every brain is wired differently. What YOU do and learn in life physically changes what your brain looks like – it literally rewires it. We used to think there were 7 categories of intelligence, but may number more than 7 billion.
6. **Attention:** We don't pay attention to boring things. What we pay attention to is profoundly influenced by memory. Our previous experience predicts where we should pay attention. Culture matters too.
7. **Memory:** Repeat to remember. The brain can only hold about seven pieces of information for less than 30 seconds! To extend the 30 seconds to a few minutes or even an hour, you will need to consistently re-expose yourself to the information.
8. **Sensory Integration:** Stimulate more of the senses. Our senses work together! Those in multisensory environments always do better than those in unisensory environments.
9. **Vision:** Vision trumps all other senses. We are incredible at remembering pictures. Our brain sees words as lots of tiny pictures, and we have to identify certain features in the letters to be able to read them. That takes time.
10. **Music:** Study or listen to boost cognition. Ideas about how music affects the brain long have been the providence of anecdote. But the research has been maturing for a while now.
11. **Gender:** Male and female brains are different. By more than 2 to 1, women are more likely to get depressed than men, a figure that shows up just after puberty and remains stable for the next 50 years. Males exhibit more antisocial behavior.
12. **Exploration:** We are powerful and natural explorers. The desire to explore never leaves us despite the classrooms and cubicles we are stuffed into. We learn, not by passive reaction to the environment but by active testing through observation, hypothesis, experiment, and conclusion.

First Principles of Instruction
(Merrill, 2013)

Regardless of model or method, instructional design theories, models and research indicate that instruction to address the following principles to facilitate learning.

Principle 1: Demonstration Principle. Instruction should: (a) provide a demonstration of the skill consistent with the type of component skill (i.e., kinds of, how-to, and what-happens); (b) provide guidance that relates demonstration to generalities; (c) engage learners in peer discussion and peer demonstration; and (d) allow learners to observe demonstration through media that are appropriate to the content.

Principle 2: Application Principle. Instruction should: (a) have learners apply learning consistent with the type of component skill (i.e., kinds of, how-to, and what-happens); (b) provide intrinsic or corrective feedback; (c) provide coaching, which should be gradually withdrawn to enhance application; and (d) engage learners in peer collaboration.

Principle 3: Task-Centered Principle. Instruction should (a) use a task-centered instructional strategy, and (b) use progression of increasingly complex whole tasks.

Principle 4: Activation Principle. Instruction should: (a) activate relevant cognitive structures in learners by having them recall, describe or demonstrate relevant prior knowledge of experience; (b) have learners share previous experiences with each other; and (c) have learners recall or acquire a structure for organizing new knowledge.

Principle 5: Integration Principle. Instruction should: (a) integrate new knowledge into learners' cognitive structures by having them reflect on, discuss, or defend new knowledge or skills; (b) engage learners in peer critiques; (c) have learners create, invent, or explore personal ways to use their new knowledge or skill; and (d) have learners publicly demonstrate their new knowledge.

How People Learn: Brain, Mind, Experience and School
(Bransford, Brown & Cocking, 2000)

Scientists and practitioners recognize that understanding learning requires multiple approaches that span multiple disciplines. ***The Science of Learning*** is an approach that recognizes the value and importance of cross-fertilization across traditional fields of study, including cognitive science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, and instructional design. In How People Learn, Bransford, Brown, and Cocking (2000) synthesize research from the "the learning sciences" to understand how learning occurs, and posit three basic findings and four related implications with the ultimate goal of optimizing learning for all.

Findings

1. Students have preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp new concepts and information, or learn them for purposes of a test but revert to their preconceptions outside the classroom.
2. To develop competence in any area, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and
    a. (c) organize knowledge in ways that facilitate retrieval and application.
3. A "metacognitive" approach to instruction can help students learn to take control of their own learning bydefining learning goals and monitoring their progress in achieving them.

Implications

1. Be learner centered (e.g. attend to students' prior KSAs and theories, cultural differences, individual progress, difficulty level).
2. Pay attention to what is taught (information, subject matter), why it is taught (understanding), and what competence or mastery looks like (application and transfer).
3. Facilitate formative assessments (ongoing assessments that make students' learning and thinking visible) and development of metacognitive skills.
4. Consider community (people and places that affect/support learning).

Make it Stick: The Science of Successful Learning
(Brown, Roediger, McDaniel, 2014)

The authors state that learning occurs through *encoding* (converting sensory perceptions to meaningful representations in the brain referred to as memory traces), *consolidation* (strengthening mental representations by reorganizing and stabilizing memory traces for long-term memory), and *retrieval* (knowledge recall based on context, recent use, and the number and vividness of cues). However, they suggest that strategies to facilitate learning are often misunderstood. For instance, the notion that when students learn better when they receive instruction in their preferred learning style is not supported by empirical research.

When learning gets harder and slower, students are often drawn to strategies that feel more fruitful, but knowledge gained from rereading, massed practice, and repetition (alone) disappear quickly, and can be deceptive, creating a false sense of mastery. Learning faster and easier (e.g., from high yield experiences) is not necessarily better. Learning is deeper and more durable when it is effortful. The authors propose learning principles by translating cognitive science research into evidence-based strategies that "make it stick."

1. **Practice retrieving new learning from memory**. Recalling facts, concepts, motor skills, problem-solving, and other events from memory is a potent learning tool. A quiz after reading or listening to a lecture produces better learning than rereading or reviewing lecture notes. Self-made flashcards and instructor-prepared tests help students monitor progress, spotting gaps and misconceptions that can be corrected through adaptive instruction.

2. **Space out retrieval practice.** Repeated, periodic practice requires reconstruction of memory that reinforces meaning, arrests forgetting, strengthens connections to prior knowledge, enhances retention, and bolsters cues and retrieval. Corrective feedback keeps students from incorrectly retaining information that may have been misunderstood. Delayed feedback produces better long-term learning than immediate feedback.

3. **Interleave practice and the study of different problems**. Interleaving practice of two or more subjects or skills (e.g., mixing problem types, performance requirements, and procedures) engages different parts of the brain, develops discrimination skills, and feels more difficult and less productive but the effort produces longer lasting learning and better transfer.

4. **Elaborate on new materials to formulate additional layers of meaning**. Giving new material meaning by expressing it in individualized terms and connecting it with prior knowledge, improves memory and develops mental cues that facilitate retrieval. Extracting underlying principles or rules that differentiate types of problems help identify the right solutions in unfamiliar situations.

5. **Reflect on learning to elaborate and practice retrieval**. Reflection is a form of practice that involves several cognitive activities that lead to stronger learning: retrieving knowledge from memory, connecting prior knowledge to new experiences, and visualizing and mentally rehearsing future performance enables better learning.

6. **Generate solutions before being shown the answer**. Struggling with problem solving primes the brain for better learning and retention. Learn from authentic experiences by setting out to accomplish a task, wading through the unknown and puzzling through problems using creativity and prior knowledge to generate and test potential solutions.

7. **Calibrate knowledge with objective feedback to avoid illusions of mastery.** Mistaking fluency with text information for mastery of underlying concepts is a common illusion that limits versatility and transfer. All new learning requires a foundation of prior knowledge. Assess, and if necessary, remediate prior knowledge to ensure access of the pre-requisites necessary to learn.

8. **Embrace difficulties**. Retrieval from short-term memory with little chance of error is an ineffective learning strategy. Effortful practice forms mental models that fuse interrelated ideas, and intellectual and motor skills into a meaningful whole that can be adapted and applied in varied circumstances. Retrieval difficulties posed by interleaving practice at different times, in different context, with different materials build interconnected knowledge networks that broaden mastery, foster conceptual learning, update multiple retrieval cues, and facilitate transfer.

9. **Avoid undesirable difficulties.** Fear of failure and chronic failure may inhibit learning by creating anxiety, an aversion to experimentation and risk-taking, and feelings of incompetence. Impediments that cannot be overcome are not desirable and may lead to learned helplessness. Constructive failure may motivate learning, promote persistence and resilience, and enhance memory by stimulating emotions.

10. **Use and formulate mnemonics.** Mnemonic devices hold information in memory, cued for ready retrieval. Memory palaces is a complex mnemonic device that organize and hold more information in memory by associating mental images with a series of physical locations to cue memories. Imagery and visual mnemonics are effective because pictures are memorable.

Applying the Science of Learning to the University and Beyond:
Teaching for Long-Term Retention and Transfer
(Halpern & Hakel, 2003)

Based on the premise that the first and only goal of colleges and universities is to teach for long-term retention, and transfer, Halpern and Hakel (2003) posit 10 basic laboratory tested principles that are said to be drawn from what we know about human learning. The following principles are excerpted verbatim from Halpern and Hakel (2003, p. 38-41).

1. ***The single most important variable in promoting long term retention and transfer is "practice at retrieval."*** Learners need to generate responses, with minimal cues, repeatedly over time with varied applications so that recall becomes fluent and is more likely to occur across different contexts and content domains. Information that is frequently retrieved becomes more retrievable; the strength of the "memory trace" for any information that is recalled grows stronger with each retrieval.

2. ***Varying the conditions under which learning takes place makes learning harder for learners but results in better learning.*** When learning occurs under varied conditions, key ideas have "multiple retrieval cues" and thus are more "available" in memory.

3. ***Learning* is *generally enhanced when learners are required to lake information that is presented in one format and "re-represent" it in an alternative format.*** Humans process information by means of two distinct channels-one for visuospatial information and one for auditory-verbal information. Information that is represented in both formats is more likely to be recalled than information that is stored in either format alone.

4. ***What and how much is learned in any situation depends heavily on prior knowledge and experience.*** Learners create new meaning using what he or she already knows. Thus, the best predictor of what is learned at the completion of any lesson, course, or program of study is what the learner thinks and knows at the start of the experience.

5. ***Learning is influenced by both our students' and our own epistemologies.*** Determining the best way for students to learn and recall something will thus depend on *what* you want learners to learn and be able to recall, what they *already know,* and their *own beliefs* about the nature of learning.

6. ***Experience alone is a poor teacher.*** Research in metacognition has shown that most people are poor judges of how well they comprehend a complex topic. Systematic and corrective feedback about the consequences of various actions is essential for facilitating experiential learning.

7. ***Lectures work well for learning assessed with recognition tests, but work badly for understanding.*** Understanding is an *interpretive* process in which students must be active participants. Learners need ''cues'' that trigger interpretation and force them to engage the material actively. The combination of large lecture classes and multiple choice tests constitutes a relatively low-cost approach to instruction but typically does not require learners to actively process information.

8. ***The act of remembering itself influences what learners will and will not remember in the future.*** Asking learners to recall particular pieces of the information they've been taught often leads to "selective forgetting" of related information that they were nor asked to recall. Frequent testing also leads to overconfidence for learners who erroneously believe that their long-term retention of the information will be better than it actually is.

9. ***Less is more, especially when we think about long-term retention and transfer.*** An emphasis on in-depth understanding of basic principles often constitutes a better instructional design than more encyclopedic coverage of a broad range of topics.

10. ***What learners do determines what and how much* is *learned, how well it will be remembered, and the conditions under which it will be recalled.*** "The head remembers what it does." What professors do in their classes matters far less than what they ask students to do both in and out of class.

Science of Learning
(Deans for Impact, 2015)

Founded in 2015, Deans for Impact is a national nonprofit organization representing leaders in educator preparation who are committed to transforming educator preparation and elevating the teaching profession. The organization is guided by four key values: (a) Data-informed improvement; (b) Common outcome measures; (c) Empirical validation of effectiveness; and (d) Transparency and accountability for results. The Science of Learning examines existing research from learning sciences and organizes findings into four sets of cognitive principles to connect research to its practical implications for teaching and learning.

Cognitive Principles (How do students understand and retain new ideas?)

1. Students learn new ideas by reference to ideas they alreadyknow.
2. To learn, students must transfer information from working memory (where it is consciously processed) to long-term memory (where it can be stored and later retrieved). Students have limited working memory capacities that can be overwhelmed by tasksthat are cognitively too demanding. Understanding new ideas can be impeded if students are confronted with too much information at once.
3. Information is often withdrawn from memory just as it went in. We usually wantstudents to remember what information means and why it is important, so they should think about meaning when they encounter to-be-remembered material.
4. Practice is essential to learning new facts, but not all practice isequivalent.

Cognitive Principles (How do students solve problems and transfer?)

5. Each subject area has some set of facts that, if committed to long-term memory, aids problem-solving by freeing working memory resources and illuminating contexts in which existing knowledge and skills can be applied. The size and content of this set varies by subject matter.
6. Effective feedback is essential to acquiring new knowledge and skills.
7. The transfer of knowledge or skills to a novel problem requires both knowledge of the problem's context and a deep understanding of the problem's underlying structure.
8. We understand new ideas via examples, but it's often hard to see the unifying underlying concepts in different examples.

Cognitive Principles (What motivates students to learn?)

9. Beliefs about intelligence are important predictors of student behavior in school.
10. Self-determined motivation (a consequence of values or pure interest) leads to better long-term outcomes than controlled motivation (a consequence of reward/punishment or perceptions of self-worth).
11. The ability to monitor their own thinking can help students identify what they do and do not know, but people are often unable to accurately judge their own learning and understanding.
12. Students will be more motivated and successful in academic environments when they believe that they belong and are accepted in those environments.

Cognitive Principles (What are common misconceptions about learning?)

13. Students do not have different "learning styles."
14. Humans do not use only 10% of their brains.
15. People are not preferentially "right-brained" or "left-brained" in the use of their brains.
16. Novices and experts cannot think in all the same ways.
17. Cognitive development does not progress via a fixed progression of age-related stages.

Learning about Learning: What Every New Teacher Needs to Know
(Pomerance, Greenberg, & Walsh, 2016)

Six strategies that are said to, "stand out for the research behind them. There is little debate among scholars about the effectiveness of these six strategies" (Pomerance, Greenberg, & Walsh, 2016, p. vi), highlight the importance of examining supporting research before adopting principles or propositions published under the pretext of the Science of Learning, Learning Science (or any class or individual theory). First, excerpts from a formal review of "Learning about Learning" is presented to note the concerns, followed by the summary of the original sources.

"As part of an ongoing series of reports by the National Council on Teacher Quality (NCTQ), Learning About Learning: What Every New Teacher Needs to Know makes broad claims about teacher education based on a limited analysis of textbooks and syllabi. The report argues that teacher education materials, specifically educational psychology and methods textbooks, are a waste of funds and do not adequately focus on what the report identifies as six essential strategies. These inadequacies, the report contends, result in ill-prepared teacher candidates lacking in "research-proven instructional strategies" (p. vi). The report offers recommendations for textbook publishers, teacher education programs, and state departments of education. However, it is not grounded in a comprehensive examination of the literature on teaching methods, and it fails to validate the evaluative criteria it employs in selecting programs, textbooks, and syllabi. The single source it relies on to justify its "six essential strategies" [Organizing Instruction and Study to Improve Student Learning: A Practice Guide, published by the Institute of Education Sciences (IES), the research arm of the U.S. Department of Education] provides limited support for NCTQ's claims. This primary source concludes, with only one exception, that the evidence supporting each of the six strategies is only moderate or weak [Table 1]. Limiting the analysis to one source that provides only tepid support renders the report of little value for improving teacher preparation, selecting textbooks, or guiding educational policy."

(Thomas & Boering, 2016, p. 1)

Table 1. NCTQ Six Strategies that Work and IES Levels of Effectiveness (Source: Organizing instruction and study to improve student learning)

NCTQ Six Strategies that Work	IES Levels of Effectiveness
pairing graphics with words	moderate
linking abstract concepts with concrete representations	moderate
posing probing questions	strong
repeating alternating problems with their solutions provided and problems that students must solve	moderate
distributing practice	moderate
assessing to boost retention	minimal

In the Review of Learning About Learning, Thomas and Boering (2016) conclude that, "Overall, the NCTQ report fails to justify the validity of its one foundational study and does not offer sufficient evidence of its methods for choosing and analyzing textbooks or course syllabi in order to reach its conclusions and recommendations. Starting with a different (and defensible) set of what teaching strategies work and then analyzing different programs and textbooks would likely produce different conclusions and recommendations. Failing its own criteria of grounding teacher preparation in research, the NCTQ guide is not an appropriate framework for analyzing the complex nature of how people learn or how teachers should teach, especially across all grade levels and content areas. From our perspective as English teachers and English educators, for example, we would not engage students in repeating alternating problems with their solutions provided and problems that students must solve" (p. 6).

What were the original strategies and how have they evolved?

In Organizing Instruction and Study to Improve Student Learning: A Practice Guide, the research arm of the U.S. Department of Education—the IES—originally distilled seven recommendations for promoting learning for all students, regardless of grade or subject, and that were said to be especially potent with struggling students, including: (1) space learning over time, (2) interleave worked examples solutions and problem-solving exercises, (3) combine graphics with verbal descriptions, (4) connect and integrate abstract and concrete representatives of concepts, (5) use quizzing to promote learning, (6) help learners allocate study time effectively, and (7) help students build explanations by asking and answering deep questions (Pashler et al. 2007).

Then, without explanations, the authors of the NCTO report changed the seven recommendations into six strategies (summarized below), that were then used to analyze 48 textbooks obtained from 48 teacher preparation programs to determine how well the text addressed the strategies. Based on the low percentage of textbooks that were found to address each strategy (ranging from 0% to 41%), the NCTQ report concluded that, "publishers and authors are failing both aspiring teachers and the teaching profession. They are not ensuring that the core texts designed to produce our next generation of teachers are giving candidates the most fundamental information needed to make learning "stick." The transfer of knowledge — from researchers to publishers to teacher educators to aspiring teachers — is not happening while the need to impart it has never been more urgent" (p. v).

The six strategies reported by NCTO (Pomerance, Greenberg, & Walsh, 2016)

The first two help students take in new information:

1. Pairing graphics with words. Young or old, all of us receive information through two primary pathways — words and graphic or pictorial representations. Student learning increases when teachers convey new material through both.
2. Linking abstract concepts with concrete representations. Teachers should present tangible examples that illuminate overarching ideas and also explain how the examples and big ideas connect.

The second two ensure that students connect information to deepen their understanding:

3. Posing probing questions. Asking students "why," "how," "what if," and "how do you know" requires them to clarify and link their knowledge of key ideas.
4. Repeatedly alternating problems with their solutions provided and problems that students must solve. Explanations accompanying solved problems help students comprehend underlying principles, taking them beyond the mechanics of problem solving.

The final two help students remember what they learned:

5. Distributing practice. Students should practice material several times after learning it, with each practice or review separated by weeks and even months.
6. Assessing to boost retention. Beyond the value of formative assessment (to help a teacher decide what to teach) and summative assessment (to determine what students have learned), assessments that require students to recall material help information "stick."

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Additional Resources on the Science of Learning

- Johns Hopkins University - Science of Learning (http://scienceoflearning.jhu.edu/)
- What is the Science of Learning (SoL) (50:04) (https://www.youtube.com/watch?v=bH6TgMM9VME)
- The New Brain Science of Learning (27:42) (https://www.youtube.com/watch?v=ahSYwchh-QM)
- SoL: How to Turn Information into Intelligence (8:26) (https://www.youtube.com/watch?v=1FvYJhpNvHY)
- The Science of Thinking (12:09) (https://www.youtube.com/watch?v=UBVV8pch1dM)
- Neuroscience, the SoL, and Educational Reform (1:34:20) (https://www.youtube.com/watch?v=y-bZidebHmA)
- The New SoL: How to Learn in Harmony with your Brain (1:50:16) (https://www.youtube.com/watch?v=7RA6ysY4FVQ)
- Want children to pay attention? Make their brains curious (23:09) (https://www.youtube.com/watch?v=ARymnvIsies)

Teacher-Directed vs. Learner-Centered Designs

For over two decades, educators have been advocating student-centered approaches to teaching and learning (e.g., APA, 1993; CTGV, 1992; Holmes Group; 1990; Brown, Collins, & Duguid, 1989). Instruction, they say, should meet the needs of individual students, promote active participation, stimulate higher-order thinking and encourage life-long learning. The challenge is trying operationalize these concepts in either a “traditional” classroom environment or in a distance education course with a class of 20 plus students within a system that is more inclined to resist change than embrace it.

Discussions with both public school and university educators suggest a number of reasons for why classroom instruction remains predominately teacher-directed. When asked about their educational philosophy or practice, educators often indicate that they are now “student-centered.” Indeed, it appears that being “student-centered” is important for most educators in the 1990’s. However, when further asked, “what do you do differently now that you are student-centered compared to when you were teacher-centered?” the majority hesitate, some of no reply and others indicate that they are now more sensitive to individual student needs and/or have students work on collaborative or cooperative group projects. While “sensitivity” and group projects may play an integral role, they do not capture the true essence of student-centered learning.

The purpose of this brief paper is to clarify and compare the differences between student-centered and teacher-directed learning. Figure 1 illustrates of the differences in terms of information flow and access among key stakeholders. Table 2 further delineates the differences between student-centered and teacher-directed learning by comparing key instructional variables. Please note: In most practical applications, no one class is either totally teacher-directed or student-centered. In actuality, learning environments typically lie somewhere in between the two extremes and at times flow from one side to the other within a course. Extremes are presented here for illustrative purposes only.

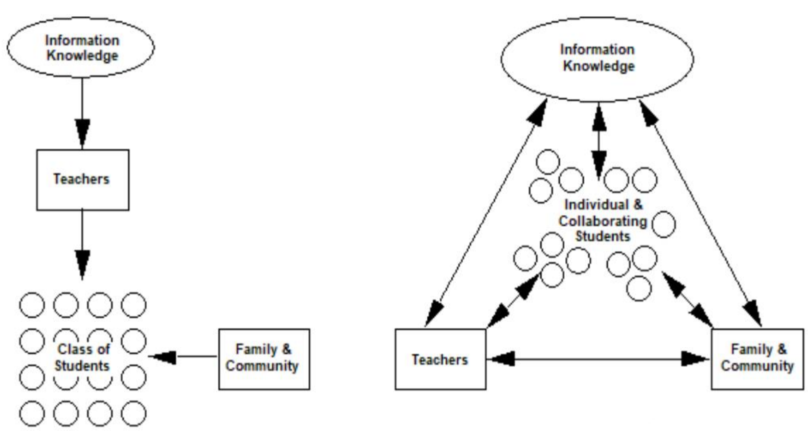

Figure 1. A comparison of teacher-centered and student-centered learning environments

Table 1. A comparison of instructional variables associated with student-centered and teacher-directed approaches to teaching and learning

Instructional Variables	**Instructional Approach**	
	Teacher-Directed	Student-Centered
Learning Outcomes	• Discipline-specific verbal information, concepts and principles. • Lower order thinking skills (e.g., recall, identify, define). • Memorization of abstract and isolated facts, figures and formulas.	• Interdisciplinary knowledge • Higher order thinking skills (e.g., problem solving) • Information processing skills (e.g., search for, access, organize, interpret, communicate information)
Goals & Objectives	• Teacher prescribes learning goals and objectives based on prior experiences, past practices, and state and/or locally mandated standards.	• Students work with teachers to select learning goals and objectives based on authentic problems and students' prior knowledge, interests and experience
Instructional Strategy	• Instructional strategy prescribed by teacher; • Group-paced, designed for "average" student • Information organized and presented primarily by teacher (e.g., lectures) with some supplemental reading assignments	• Teacher works with students to determine learning strategy • Self-paced, designed to meet needs of individual student • Student given direct access to multiple sources of information (e.g., books, on-line databases, community members)
Assessment	• Assessments used to sort students • Paper & pencil exams used to assess students acquisition of information • Teacher sets performance criteria for students • Students left to find out what teacher wants	• Assessment integral part of learning • Performance based, used to assess students ability to apply knowledge • Students work with teachers to define performance criteria • Student develop self-assessment and peer assessment skills
Teachers' Role	• Teacher organizes and presents information to group of students • Teacher acts as gatekeeper of knowledge, controlling students access to information • Teacher directs learning	• Teacher provide multiple means for accessing information • Teacher acts as facilitator, helps students access and process information • Teacher facilitates learning
Students' Role	• Students expect teachers to teach them what's required to pass the test • Passive recipients of information • Reconstructs information	• Students take responsibility for learning • Active knowledge seekers • Constructs knowledge and meaning
Environment	• Students sit individually in rows, information presented primarily via lectures and reading assignments.	• Students work at stations, individually and in small groups, with access to electronic resources.

Models and Tactics for Engaging Learners and Promoting Active Learning

Three diagrams help to explain and predict learner engagement, including a model illustrating (a) flow state (b) learning engagement, and (c) Yerkes-Dodson Law of human arousal and performance.

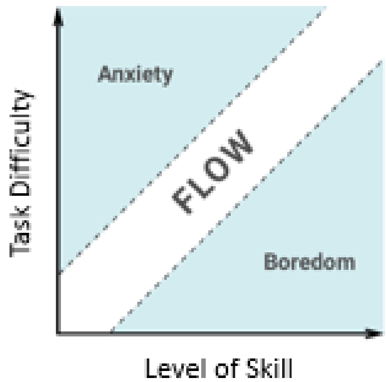

Figure 1. Factors affecting flow state

Figure 1 depicts the relationship between task difficulty and the skill of the person performing the task. According to Csikszentmihályi (1990) Flow Theory, task difficulty must match a person's skill level to promote a state of flow.

Figure 2 indicates that learner engagement is based two distinct factors, the design of: (a) the learning resource, and (b) the learning activity. According to Learner Engagement theory (Collins & McNaught, 2002) a resource that is multisensory and interactive, coupled with a learning task that is also interactive will result in a highly engaging learning experience.

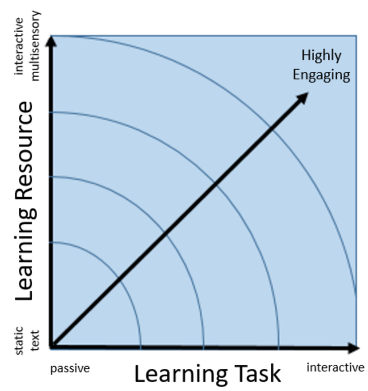

Figure 2. Learner Engagement Model

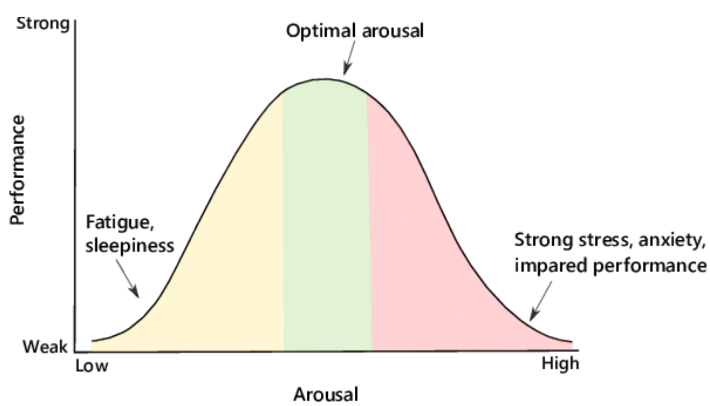

Figure 3. Yerkes-Dodson inverted U depicting the curvilinear nature of human behavior

Yerkes-Dodson Law dictates that human performance increases, but only with optimal levels of mental arousal. When levels of arousal become either too high or too low, performance decreases. Keller (1996) utilizes the law to also suggest that optimal levels of attention, relevance, confidence, and satisfaction enhance learner performance. In other words, if a learner perceives too much or too little attention, relevance, confidence or satisfaction, their performance will decrease (e.g., learners with too much or little confidence). The curvilinear relationship between a stimulus and human behavior differs from the theories modeled in Figures 1 and 2 that suggest mental constructs, such as engagement and flow, act in a linear manner.

Tactics for Enhancing Learner Engagement and Active Learning

From 5E Instructional Model (BSCS, 2005)

To Engage Learners	*To Promote Exploration*
• Demonstration • Unusual or counter-intuitive events • Provoking pictures, objects, sounds, • Free Write • Question and Answer • Problem Creation • Brainstorming • Sense of Mystery	• Perform an investigation • Observe natural events • Read authentic resources collect info • Review the work of others • Solve a problem • Construct a model or framework • Watch video • Handle manipulative • Explore Internet sites • Read interesting, provoking passages

From ARCS Model of Motivational Design (Keller, 1987a, 1987b)

Perceptual Arousal - What can I do to capture students' interest?
- Sensory effects - Use pictures, objects, sounds, smells, and tastes that gain learners' attention.
- Absence of distraction - Use all stimulus materials judiciously

Inquiry Arousal - How can I stimulate students' curiosity?
- Active responding - Engage the learners' interest by using question-response-feedback interactions that require active thinking.
- Problem creation - Allow learners to create their own problems to solve and judge their solutions or present the consequences.
- Sense of mystery - Present problem solving situations in a context of exploration and partial revelations of knowledge.
- Unusual content or events - Use unusual, contradictory, or bizarre content.

Interactive Techniques compiled by Yee (2019)

Tactics for Engaging Large Groups
1. Picture Prompt - Show students an image with no explanation, and ask them to identify/explain it, and justify their answers. Or ask students to write about it, or to name the processes and concepts shown.
2. Updating Notes - Take a break and encourage students to compare their class notes so far with other students, fill in gaps, develop joint questions, and most importantly, update and rewrite their notes.
3. Choral Response - Ask a one-word answer to the class at large; volume of answer (graphically depicted by Word Clouds or numerically depicted by responses to pool) suggest degree of comprehension, interest, or approval.
4. Grab a Volunteer - After a minute paper (or better: think pair share) pick one student to read, interpret and/or explain another student's answer.
5. Questioning - The instructor replaces lecture by peppering students with questions, always asking the next question in a way that guides the conversation toward a learning outcome. Variation: A group of students writes a series of questions as homework and leads the exercise in class.

Tactics for Engaging Small Groups
1. **Pass the mike** - Whoever has the mike must answer your question. They then pass it on to the student of their choice.
2. **Three Port Interview** - Pose the following question to the entire class: "What do you think are the three biggest issues related to__." Choose students to share their 3 responses to the question for one minute.
3. **Infographic** - Students use online services (https://visual.ly/view) to create an infographic that combines flowchart logic and visual presentation

4. **Concept Mapping-** Students write keywords onto sticky notes and then organize them into a flowchart. Could be less structured: students simply draw the connections they make between concepts.
5. **Word Journal** - First, summarize the entire topic on paper with a single word. Then use a paragraph to explain your word choice.
6. **Objective Check** - Students write a brief essay in which they evaluate to what extent their work fulfills an assignment's objectives.
7. **Student Storytelling** - Students are given assignments that make use of a given concept in relation to something that seems personally relevant (such as requiring the topic to be someone in their family

Tactics for Engaging Pairs

1. **Storytelling Gaps** - One partner relays a story that summarizes learning in the chapter so far, but leaves out crucial fine information (such as dates that should have been memorized). The partner listens and records dates silently on paper as the story progresses and then updates the first person.
2. **Do-Si-Do-** Students do partner work first, then sound off by twos. All of the 2's stand up and find a new partner (the l's are seated and raise their hands until a new partner comes), then debrief what was said with the first partner. Variation: Later, all the 1's come together in a large circle for a group debrief, while the 2's have their own circle.
3. **Forced Debate** - Students debate in pairs, defending either their preferred position or the opposite of their preferred position. Variation: Half the class takes one position, half the other. The two halves line up, face each other, and debate. Each student may only speak once, so that all students oaboth sides can engage the issue.
4. **Optimist/Pessimist-** In pairs, students take opposite sides of a conversation. This technique can be applied to case studies and problem solving as well.
5. **Teacher and Student** - Individually brainstorm the main points of the last homework, then assign roles of teacher and student to pairs. The teacher's job is to sketch the main points, while the student's job is to cross off points on his list as they are mentioned, but come up with 2-3 ones missed by the teacher.
6. **Peer Review Writing Task** - To assist students with a writing assignments, encourage them to exchange drafts with a partner. The partner reads the essay and writes a three paragraph response: the first paragraph outlines the strengths of the essay, the second paragraph discusses the essay's problems, and the third paragraph is a description of what the partner would focus on in revision.
7. **Student Pictures**- Ask students to bring or draw a pictures to illustrate a specific concept to their working groups.

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Grounded Strategies for Instructional Design

Grounded instructional strategies are rooted in established theories and research on human learning. They form the basis for designing and sequencing meaningful e-learning interactions and for creating online, blended and classroom learning environments. Instructional strategies grounded in research and theory are outlined and compiled to facilitate the instructional design of training and educational programs. Gaining further understanding is recommended when interested in a particular strategy by reading related reference.
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Grounded Instructional Strategies

Table 1 outlines primary instructional events associated with published instructional strategies that are grouped according to major classes of learning theories. Guidelines and criteria for selecting a grounded strategy follow, along with further details about each strategy.

Table 1. Primary events associated with grounded instructional strategies

Constructivist (Learner-Centered) Approaches		
Experiential Learning (Pfeiffer & Jones, 1975) 1. Experience 2. Publish 3. Process 4. Internalize 5. Generalize 6. Apply	**Experiential Learning Model** (Kolb, 1984) 1. Concrete experience 2. Reflective observation 3. Abstract conceptualization 4. Active experimentation	**Guided Experiential Learning** (Clark, 2004) 1. Goals 2. Reasons and activation 3. Demonstration 4. Application 5. Integration 6. Assessment
Learning by Doing (Schank, Berman & Macpherson, 1999) 1. Define goals 2. Set mission 3. Present cover story 4. Establish roles 5. Operate scenarios 6. Provide resources 7. Provide feedback	**Problem-Based Learning** (Barrows, 1985; Boud & Feletti, 1997) 1. Start new class 2. Start new problem 3. Problem follow-up 4. Performance presentation(s) 5. After conclusion of problem	**Collaborative Problem-Solving** (Nelson, 1999) 1. Build readiness 2. Form and norm groups 3. Determine preliminary problem 4. Define and assign roles 5. Engage in problem-solving 6. Finalize solution 7. Synthesize and reflect 8. Assess products and processes 9. Provide closure
Problem Solving: Story Problems (Jonassen, 2011) 1. Present story problem 2. Compare to analogies 3. Parse problem sets 4. Generate equation/algorithm 5. Solve problem 6. Check answer	**Problem Solving: Decision Making** (Jonassen, 2011) 1. Present problem/case 2. Compare to similar cases or analogies 3. Generate options 4. Analyze options 5. Make decision 6. Report selection	**Problem Solving: Troubleshooting** (Jonassen, 2011) 1. Present problem/case in simulation 2. Refer to system model 3. Call on cases library (worked examples) 4. Practice troubleshooting

Grounded Instructional Strategies

Table 1 outlines primary instructional events associated with published instructional strategies that are grouped according to major classes of learning theories, including constructivist (learner-centered), behavioral and cognitive information processing, and neurobiological approaches to explaining how and why people learn. Guidelines and criteria for selecting a grounded strategy follow, along with further details about each strategy.

Table 1. Primary events associated with grounded instructional strategies

Constructivist (Learner-Centered) Approaches		
Experiential Learning (Pfeiffer & Jones, 1975) 1. Experience 2. Publish 3. Process 4. Internalize 5. Generalize 6. Apply	**Experiential Learning Model** (Kolb, 1984) 1. Concrete experience 2. Reflective observation 3. Abstract conceptualization 4. Active experimentation	**Guided Experiential Learning** (Clark, 2004) 1. Goals 2. Reasons and activation 3. Demonstration 4. Application 5. Integration 6. Assessment
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Problem Solving: Story Problems (Jonassen, 2011) 1. Present story problem 2. Compare to analogies 3. Parse problem sets 4. Generate equation/algorithm 5. Solve problem 6. Check answer	**Problem Solving: Decision Making** (Jonassen, 2011) 1. Present problem/case 2. Compare to similar cases or analogies 3. Generate options 4. Analyze options 5. Make decision 6. Report selection	**Problem Solving: Troubleshooting** (Jonassen, 2011) 1. Present problem/case in simulation 2. Refer to system model 3. Call on cases library (worked examples) 4. Practice troubleshooting
Problem Solving: Strategic (Jonassen, 2011) 1. Present simulation of typical and atypical cases 2. Recognize key components 3. Discriminate typical and atypical situations 4. Take action based on nature of situation 5. Provide feedback 6. Reflect on actions	**Problem Solving: Policy Analysis** (Bardach, 2000) 1. Define the problem 2. Assemble evidence 3. Construct alternatives 4. Select and apply criteria 5. Project outcomes 6. Confront trade-offs 7. Make decision 8. Tell your story	**Problem Solving: Design** (Dym & Little, 2004) 1. Problem Definition 2. Conceptual Design 3. Preliminary Design 4. Detailed Design 5. Final Design

Table 1 (con't). Primary events associated with grounded instructional strategies

Constructivist (Learner-Centered) Approaches (con't)		
BSCS 5E Model (BSCS, 2005; Bybee, 2002) 1. Engage 2. Explore 3. Explain 4. Elaborate 5. Evaluate	**WebQuest** (Dodge, 1998) 1. Introduction 2. Task 3. Process 4. Resources 5. Evaluation 6. Conclusion	**Case-Based Reasoning** (Aamodt & Plaza, 1994) 1. Present New Case 2. Retrieve Similar Cases 3. Reuse Information 4. Revise Proposed Solution 5. Retain Useful Experiences
Simulation Model (Joyce, Weil, & Showers, 1992) 1. Orientation 2. Participant Training 3. Simulation Operations 4. Participant Debriefing 5. Appraise and redesign the simulation	**Inquiry Training** (Joyce, Weil, & Showers, 1992) 1. Confrontation with the Problem 2. Data Verification 3. Data Experimentation 4. Organizing, Formulating and Explanation 5. Analysis of inquiry process	**Inductive Thinking** (Taba, 1967) 1. Concept Formation 2. Interpretation of Data 3. Application of Principles
Jurisprudential Inquiry (Oliver & Shaver, 1971) 1. Orientation to the Case 2. Identifying the Issues 3. Taking Positions 4. Exploring the Stance(s) 5. Refining and Qualifying the Positions 6. Testing Factual Assumptions Behind Qualified Positions	**Scaffolded Vee Diagram** (Crippen, Archambault, & Kern, in press) 1. Big Problem 2. Initial Ideas 3. Concept Map 4. Analysis and Artifacts 5. Claims 6. Expert Opinion 7. Reflection	**Historical Inquiry** (Waring, 2011) 1. A Hook 2. Identify Fundamental Questions 3. Engage in Primary and Secondary Sources 4. Recognize Multiple Perspectives and Historic Causation 5. Create Plausible Narratives 6. Assess Skills, Knowledge and Attitudes 7. Reflect on Experience
Adaptive Instructional Design (Schwartz, Lin, Brophy & Bransford, 1992) 1. Look Ahead & Reflect Back 2. Present Initial Challenge 3. Generate Ideas 4. Present Multiple Perspectives 5. Research and Revise 6. Test Your Mettle 7. Go Public 8. Progressive Deepening 9. General Reflection and Decisions 10. Assessment	**Eight Events of Student-Centered Learning** (Hirumi, 2002, 1998, 1996) 1. Set Learning Challenge 2. Negotiate Goals and Objectives 3. Negotiate Learning Strategy 4. Construct Knowledge 5. Negotiate Performance Criteria 6. Assess Learning 7. Provide Feedback (Steps 1-6) 8. Communicate Results	**Constructivist Learning** (Jonassen, 1999) 1. Select Problem 2. Provide Related Case 3. Provide Information 4. Provide Cognitive Tools 5. Provide Conversation Tools 6. Provide Social Support

Table 1 (con't). Primary events associated with grounded instructional strategies

Behavioral & Cognitive Information Processing (Teacher-Directed) Approaches		
Nine Events of Instruction (Gagne, 1977, 1974) 1. Gain Attention 2. Inform Learner of Objective(s) 3. Recall Prior Knowledge 4. Present Stimulus Materials 5. Provide Learning Guidance 6. Elicit Performance 7. Provide Feedback 8. Assess Performance 9. Enhance Retention and Transfer	**5 Component Lesson Model** (Dick, Carey, & Carey, 2009) 1. Pre-Instructional Activities 2. Content Presentation and Learning Guidance 3. Learner Participation 4. Assessment 5. Follow Through Activities	**Elements of Lesson Design** (Hunter, 1990) 1. Anticipatory Set 2. Objective and Purpose 3. Input 4. Modeling 5. Check for Understanding 6. Guided Practice 7. Independent Practice
Direct Instruction (Joyce, Weil, & Showers, 1992) 1. Orientation 2. Presentation 3. Structured Practice 4. Guided Practice 5. Independent Practice		
Neurobiological Approaches		
Brain Rules (Medina, 2014) 1. **Survival:** The human brain evolved. 2. **Exercise:** Boosts brain power. 3. **Sleep:** Sleep well, think well. 4. **Stress:** Stress inhibits learning. 5. **Wiring:** Every brain is wired differently. 6. **Attention:** Avoid boring things. 7. **Memory:** Repeat to remember. 8. **Sensory Integration:** Stimulate senses. 9. **Vision:** Vision trumps all other senses. 10. **Music:** Listening boosts cognition. 11. **Gender:** Male/female brains differ. 12. **Exploration:** We are natural explorers.	**Brain-Based Teaching** (Jensen, 2005) 1. Malleable memories 2. Non-conscious experience runs automated behaviors 3. Reward and addiction dependency 4. Attentional limitations 5. Brain seeks and creates understanding 6. Rough drafts/Gist learning 7. Input limitations 8. Perception influences our experience 9. Malleability/Neural plasticity 10. Emotional-Physical state dependency	**Interplay Strategy** (Hirumi et al., under review; Hirumi & Stapleton, 2014; Stapleton & Hirumi, 2011) 1. Expose 2. Inquire 3. Discover 4. Create 5. Experiment 6. Share
Principles of Natural Learning (Caine, Caine, McClintic & Klimek, 2005) 1. Relaxed Alertness a. Challenge enhances, threat inhibits b. Social brain/mind c. Innate search for meaning d. Emotions are critical to patterning 2. Orchestrated Immersion a. The brain processes parts and whole b. All learning engages the physiology. c. Meaning occurs through patterning d. Learning is developmental 3. Active Processing a. Declarative and procedural memory b. Focused attention & peripheral perception. c. Conscious and unconscious. d. Each brain is uniquely organized.		

Table 1 (con't). Primary events associated with grounded instructional strategies

Alternative Approaches		
4Mat System (McCarthy, 1987)	**SQR** (Maier, 1990)	**SQ3R** (Robinson, 1961)
1. Create an experience 2. Reflect/Analyze experience 3. Integrate reflective analysis 4. Develop concepts/skills 5. Practice defined "givens" 6. Practice adding something 7. Analyze application 8. Apply to new experience	1. Summarize 2. Question 3. Response	1. Survey 2. Question 3. Read 4. Recite 5. Review

Grounding your Designs

Grounded design is "the systematic implementation of processes and procedures that are rooted in established theory and research in human learning (Hannafin, Hannafin, Land, & Oliver, 1997, p.102)." Four conditions are basic to grounded design:

- Designs must be rooted in a defensible theoretical framework;
- Methods must be consistent with the outcome of research conducted to test, validate, or extend the theories upon which they are based;
- Designs must be generalizable to situations beyond the unique conditions in which they are being utilized; and
- Grounded designs and their frameworks must be validated iteratively through successive implementation.

Without a solid grounding in theory, educational activities, whatever their intent, represent "craft-based" approaches to instruction, solutions carved by one person for one specific environment. This is not to say that such activities are ineffective, only that they may not be applicable to circumstances beyond those in which they were initially employed. Grounding the design of your instruction helps you explain and predict the results of your instruction by identifying key variables that affect student learning. It enables you to continuously improve your designs as well as add to the knowledge base of the theory and strategy you applied.

Application of a grounded instructional strategy guides the overall design and sequencing of key learning interactions. Selection of an appropriate strategy requires the instructor and/or instructional designer to consider the desired learning outcomes as well as his or her personal values and beliefs about teaching and learning (Hirumi, 2013). It may also require the instructor and the instructional designer to step out of his or her comfort zone, applying a strategy that s/he may have yet to experience.

A fundamental systematic design principle is that the nature of the desired **learning outcomes** should drive the instructional design process. For instance, the specific technique used to analyze an instructional situation should be based on targeted learning outcomes (Jonassen, Tessmer & Hannun, 1999). Similarly, learner assessment methods should be determined by the nature of specified objectives (Berge, 2002; Hirumi, 2002d). The same principle applies to the selection of a grounded instructional strategy.

For example, to teach people how to use of a new photocopying machine (a relatively simple procedure), a teacher-directed instructional strategy may be more effective and efficient than constructivist or learner-centered approaches. In cases where there is basically one correct answer and/or one correct method for deriving the answer, learners do not necessarily have to interact with others learners to derive meaning and construct their own knowledge through social discourse. In contrast, if the desired learning outcome requires higher-order thinking, where there may be more than one correct answer or more than one method for deriving the correct answer, then more learner-centered or related problem-based approaches to teaching and learning may be appropriate.

In selecting an appropriate strategy, it is also important to take in account the instructor's **educational philosophy and epistemological beliefs**. If the instructor believes that people derive meaning and construct knowledge through social interactions, then constructivist, learner-centered, and cooperative instructional strategies may support his or her beliefs. In contrast, if the instructor or designer believes people learn by processing information through sensory, short-term, and long-term memory, than an instructional strategy based on information processing theories of learning, like Gagne's Nine Events of Instruction (Gagne, 1977), may resonate with his or her educational philosophy. If the instructor is a pragmatist and believes that meaning is constructed by individuals based on their interpretation and understanding of reality, s/he may take an eclectic approach, selecting from a range of behaviorist to constructivist instructional strategies depending on the situation. Furthermore, if and instructional designer is working with an instructor and/or subject matter expert to create the online materials, then it may be important to discuss and, if necessary, reconcile any differences in philosophy prior to initiating any designs.

Selecting an appropriate instructional strategy is neither simple, nor straight-forward. Much depends on the desired learning goals and objectives, but concerns for the learner, the context and beliefs held by the teacher or instructional designer also mediate the selection process. Perhaps even a stronger influence is time and expertise. With insufficient time or training, educators often revert to what they know best; that is, teacher-directed methods and materials. To select an appropriate instructional strategy, the instructor and/or designer must have the time and skills necessary to analyze several important variables. They must also have the confidence, desire and the opportunity to apply alternative instructional strategies within the context of their job.

Inquiry, Experiential and Problem-Based (Learner-Centered) Approaches

Experiential Learning Model
(Pfeiffer & Jones, 1975)

Based on the belief that people learn best by doing, the experiential learning model can start with didactic (passive) forms of instruction but soon progresses to experiential (active) forms of learning.

1. **Experience** – Immerse learner in "authentic" experience (e.g., real or simulated job task).
2. **Publish** – Talking or writing about experience. Sharing observations, thoughts, and feelings.
3. **Process** – Debrief: Interpret published information, defining patterns, discrepancies and overall dynamics, making sense of the information generated by group.
4. **Internalize** – Private process, learner reflects on lessons learned, means of managing conflicting data and requirements for future learning.
5. **Generalize** – Develop hypotheses, form generalizations and reach conclusions from information and knowledge gained from lesson.
6. **Apply** – Use information and knowledge gained from lesson to make decisions and solve problems.

Experiential Learning
(Kolb, 1984)

Building upon earlier work by John Dewey and Kurt Levin, American educational theorist Kolb believed that "learning is the process whereby knowledge is created through the transformation of experience" (1984, p. 38). The theory presents a cyclical model of learning, consisting of four stages shown below. One may begin at any stage, but must follow each other in the sequence:

1. **Concrete experience** (or "DO") - Where the learner actively experiences an activity such as a lab session or field work.
2. **Reflective observation** (or "OBSERVE") - When the learner consciously reflects back on that experience.
3. **Abstract conceptualization** (or "THINK") - Where the learner attempts to conceptualize a theory or model of what is observed
4. **Active experimentation** (or "PLAN") - Where the learner is trying to plan how to test a model or theory or plan for a forthcoming experience

Kolb's four-stage learning cycle shows how experience is translated through reflection into concepts, which in turn are used as guides for active experimentation and the choice of new experiences. Kolb identified four learning styles which correspond to these stages. The styles highlight conditions under which learners learn better. These styles are:

- Assimilators, who learn better when presented with sound logical theories to consider
- Convergers, who learn better when provided with practical applications of concepts and theories
- Accommodators, who learn better when provided with "hands-on" experiences
- Divergers, who learn better when allowed to observe and collect a wide range of information

Guided Experiential Learning

(Clark, 2004)

Clark's (2004) Guided Experiential Learning (GEL) fosters skill development and the learning of factual information in the context of how it will be used. It assumes that learning occurs best in context of a goal that is relevant, meaningful, and interesting to students; and (b) content knowledge is best learned in context of relevant tasks closely related to how students will use it outside of the learning environment.

1. **Goals** – Including learning objectives, problems to be solved, what students will be able to do at the end of the lesson.
2. **Reasons and Activation** – Rationale and overview for the goals and objectives. Answers questions about value and utility such as: "Why is learning to do this important to me?" "What value does it hold for me, my job, mission or my team?" "What risk will I avoid if I learn it?" Briefly describe (and when possible, provide a visual model of the location of) the lesson in the larger course and sequence of lessons and then describe the instructional strategy
3. **Demonstration** – Promotes learning by demonstrating what is to be learned rather than merely telling information about what is to be learned. The demonstration can direct students to relevant information and provide multiple representations or scenarios for comparison. The demonstration should also be accompanied by job aids that summarize the action and decision steps.
4. **Application** – Students are required to use their new knowledge or skill to solve problems or show comprehension of new concepts.
5. **Integration** – Students are encouraged to integrate (transfer) the new knowledge or skill by the following activities:
   - 1.1 Watch me: Gives students the opportunity to publicly demonstrate their new knowledge or skill.
   - 1.2 Reflection: Asks students to reflect-on, discuss, and defend their new knowledge or skill.
   - 1.3 Creation: Encourages students to create, invent, and explore new and personal ways to use their new knowledge.
6. **Assessment** – Practice must be reviewed and checked against a list of concepts or action and decision steps derived from standard procedures.

Learning by Doing
(Schank, Berman & Macpherson, 1999)

The primary goal is to foster skill development and the learning of factual information in the context of how it will be used. Assumes that learning occurs best in context of a goal that is relevant, meaningful, and interesting to students, and when content knowledge is learned in context of relevant tasks closely related to how students will use it outside of the learning environment.

1. **Define Goals**
   1.1 Process knowledge goals
   1.2 Content knowledge goals
2. **Set Mission**
   2.1 Must be motivational
   2.2 Must be somewhat realistic
3. **Present Cover Story**
   3.1 Must be motivating and create the need for the mission
   3.2 Must allow opportunities to practice the skills and seek the knowledge
4. **Establish Roles** (who the students will play)
   4.1 Must be one who uses the necessary skills and knowledge
   4.2 Must be motivating
5. **Operate Scenarios**
   5.1 Must be closely related to both the mission and the goals
   5.2 Must have decision points with consequences that become evident
   5.3 The consequences must indicate progress toward completing the mission
   5.4 A negative consequence must be understand as an expectation failure
   5.5 Plenty of operations for students to do (most time practicing skills)
   5.6 Should not require more than what the goals call for
6. **Provide Resources**
   6.1 Provide the information the students need to succeed in their mission
   6.2 Information must be well organized and readily accessible
   6.3 Information is often best provided in the form of stories
7. **Provide Feedback**
   7.1 Must be situated, so it is indexed properly as an expectation failure
   7.2 Must be just-in-time, so the student will use it
   7.3 Can be given in three ways (a) consequences of actions, (b) coaches, (c) domain experts' stories about similar experiences.

Problem-Based Learning
(Barrows, 1985; Boud & Feletti; 1997)

Disenchanted with medical students' ability to apply information learned from lectures, Barrow's developed this model to enhance transfer.

1. **Start New Class**
   1.1 Introductions
   1.2 Climate Setting (including teacher/tutor role)
2. **Start New Problem**
   2.1 Set problem
   2.2 Bring problem home
   2.3 Describe the product/performance required
   2.4 Assign tasks
   2.5 Reason through the problem (i.e., ideas/hypotheses, facts, learning issues and action plan).
   2.6 Commitment as to probable outcome
   2.7 Learning issues shaping/assignment
   2.8 Resource identification
   2.9 Schedule follow-up
3. **Problem Follow-Up**
   3.1 Resources used and their critique
   3.2 Reassess the problem (i.e., ideas/hypotheses, facts, learning issues and action plan).
4. **Performance Presentation(s)**
5. **After Conclusion of Problem**
   5.1 Knowledge abstraction and summary
   5.2 Self-evaluation

Collaborative Problem-Solving
(Nelson, 1992)

The goals are to develop content knowledge in complex domains, problem-solving and critical thinking skills, and collaborative skills. It should only be used when those types of learning are paramount and when the students and instructor are receptive to this approach to learning, with its shift in roles and power relationships.

1. **Build Readiness**
   - 1.1 Overview of collaborative problem solving process
   - 1.2 Develop an authentic problem or project to anchor instruction
   - 1.3 Provide instruction and practice in group process skills
2. **Form and Norm Groups**
   - 2.1 Form small heterogeneous work groups
   - 2.2 Encourage groups to establish operational guidelines
3. **Determine Preliminary Problem**
   - 3.1 Negotiate a common understanding of the problem
   - 3.2 Identify learning issues and goals
   - 3.3 Brainstorm preliminary solutions or project plans
   - 3.4 Select and develop initial design plan
   - 3.5 Identify sources of needed resources
   - 3.6 Gather preliminary information to validate the design plan
4. **Define and Assign Roles**
   - 4.1 Identify the principal roles needed to complete the design plan
   - 4.2 Negotiate the assignment of roles
5. **Engage in Problem-Solving**
   - 5.1 Refine and evolve the design plan
   - 5.2 Identify and assign tasks
   - 5.3 Acquire needed information, resources, and expertise
   - 5.4 Disseminate acquired information, resources, and expertise to group
   - 5.5 Engage in solution or project, report contributions and group activities
   - 5.6 Participate in intergroup collaborations and evaluations
   - 5.7 Conduct formative evaluations of the solution or project
6. **Finalize Solution**
   - 6.1 Draft the final version of solution or project
   - 6.2 Conduct final evaluation or usability test of the solution or project
   - 6.3 Revise and complete the final version of the solution or project
7. **Synthesize and Reflect**
   - 7.1 Identify learning gains
   - 7.2 Debrief experiences and feelings about the process
   - 7.3 Reflect on group and individual learning processes
8. **Assess Products and Processes**
   - 8.1 Evaluate the products and artifact created
   - 8.2 Evaluate the processes used
9. **Provide Closure**

Problem-Solving: Story/Word Problems
(Jonassen, 2011)

One of the most common types of problems presented to students in primary, secondary and post-secondary education, story problems are typically solved by identifying key values in a short story, and selecting and applying an appropriate algorithm to generate a correct answer. Contemporary approaches to story problems emphasize a conceptual understanding of the problem before generating an answer.

1. **Present word problem.** Provide structural or situational models and/or instruction to help learners classify the problem.
2. **Compare to analogies.** Provide analogous problems to compare current problem.
3. **Parse problem set.** Provide identifiers to help learners analyze and identify key values and factors to consider in solving the problem.
4. **Generate equation/algorithm.** Provide equation builders and calculators to help learners solve the problem.
5. **Solve problem.**
6. **Check answer.**

Problem-Solving: Decision Making
(Jonassen, 2011)

Decision making is the most common type of problem we face in everyday life. Decision making is also central to solving other types of more complex problems. In short, decisions are made by selecting one or more potentially useful or fulfilling options from a larger set of options. Decisions are made be made from a list of options, selecting or rejecting a particular option, or by formulating and evaluating options.

1. **Present problem/case**
2. **Compare to similar cases or analogies**
3. **Generate options**
    a. Construct decision matrix
    b. Construct choice set
    c. Conduct force field/SWOT analysis
4. **Analyze options**
5. **Make decision**
6. **Report selection**

Problem-Solving: Troubleshooting and Diagnosing
(Jonassen, 2011)

People are often tasked with troubleshooting or diagnosing a problem. The simplest form of troubleshooting consists of finding a faulty component in a device and either repairing or replacing it. More complex forms requires professionals to diagnose a physical or mental problem. People may use analytical reasoning skills or use analogies based on examples to diagnose problems. It's important to keep in mind that if one is good at troubleshooting or diagnose one type of problem does not mean they are good at troubleshooting or diagnosing other kinds of problem.

1. **Present problem/case in simulation**
2. **Refer to system model**
3. **Call on case library (worked examples)**
4. **Facilitate use of analytical and/or analogical reasoning skills**
5. **Practice troubleshooting/diagnosing**
6. **Provide feedback**

Problem-Solving: Strategic
(Jonassen, 2011)

Strategic problem solving is a multifaceted activity that requires the use of complex strategies while maintaining situational awareness. They often occur under uncertain conditions that make them ill-structured. Expert problem solvers often base decisions on experience; they see situations as a prototype of what they've seen before and take actions without considering many options. Experts use pattern recognition rather than deductive reasoning to solve strategic problems. Thus, presenting many cases is essential for developing strategic as well as diagnostic problem solving skills.

1. **Present simulation of typical and atypical cases**
2. **Recognize key components**
   a. Relevant cues
   b. Plausible goals
   c. Expectations
3. **Discriminate typical and atypical situations**
4. **Take action based on nature of situation**
5. **Provide feedback**
6. **Reflect on actions**

Problem-Solving: Policy Analysis
(Bardach, 2000)

Policy problems are often complex, involving many people, such as planners, analysts, managers, legislators, citizens, and other stakeholders. Solving problems with policy is complex because different stakeholders typically hold different values and beliefs, and seek different outcomes that are difficult to equate. Most policy problems are economic but have political, social, environmental, emotional and other implications.

1. **Define the problem.** Be clear about the nature and extent of the problem.
2. **Assemble evidence.** Assess policies that others have used to assess the nature and extent of the problem being defined.
3. **Construct alternatives.** Model alternatives, identifying causal relationships and related incentives and constraints.
4. **Select and apply criteria.** Evaluate alternatives by selecting and applying evaluation criteria (e.g., for efficiency, equality, fairness, freedom, legality).
5. **Project outcomes.** Predict possible by constructing scenarios.
6. **Confront trade-offs.** Compare and contrast alternatives using a decision matrix.
7. **Make decision.**
8. **Tell your story.** Communicate decisions along with rationale for the decisions.

Problem-Solving: Design
(Dym & Little, 2004)

Professionals in and across disciplines solve design problems to create products, processes, systems, activities, and a many other outcomes. Needless to say, different people use different methods with vary assumptions within and across disciplines to solve design problems. The following is an example of an engineering design process.

1. **Problem Definition**: From the client statement, clarify objectives, establish user requirements, identify constraints, and establish functions of product by providing a list of attributes.
2. In the **Conceptual Design** phase, establish design specifications and generate alternatives.
3. In the **Preliminary Design** phase, create model of design and test and evaluate the conceptual design by creating morphological charts or decision matrices.
4. During **Detailed Design**, refine and optimize the chosen design.
5. For the **Final Design**, document and communicate the fabrication specifications and the justifications for the final design.

BSCS 5E Model
(BSCS, 2005;
Bybee, 2002)

The natural inquiry of children and problem-solving of adults follow a pattern of initial engagement, exploration of alternatives, formation of explanations, use of the explanations, and evaluation of the explanations based on efficacy and others. Activities encourage conceptual change and a progressive reforming of ideas.

1. **Engage** activities provide the opportunity for teachers to identify students' current concepts and misconceptions. Although provided by a teacher or structured by curriculum materials, these activities introduce major ideas in problem situations. How do students' explain this situation?
2. **Explore** activities provide a common set of experiences for students and opportunities for them to "test" their ideas with their own experiences and those of peers and the teacher. How do students' exploration and explanation of experiences compare with others?
3. **Explain** activities provide opportunities for students to use their previous experiences to recognize misconceptions and to begin making conceptual sense of the activities through construction of new ideas and understandings. Allows introduction of formal language, terms and content information that makes students' previous experiences easier to describe and explain.
4. **Elaborate** activities apply or extend the student's developing concepts in new activities and relate their previous experiences to the current activities. How does the new explanation work in a different situation?
5. **Evaluate** activities serve as a summative assessment of what students know and can do. How do students understand and apply concepts and abilities?

WebQuest

(Dodge, 1998)

WebQuest is an inquiry-oriented strategy in which most or all of the information used by learners is drawn from the Web.

1. **The Introduction** orients students and captures their interest
2. **The Task** describes the activity's end product
3. **The Process** explains strategies students should use to complete the task
4. **The Resources** are the Web sites students use to complete the task
5. **The Evaluation** measures the results of the activity
6. **The Conclusion** sums up the activity and encourages students to reflect on its process and results

Case-Based Reasoning
(Aamodt & Plaza, 1994)

Case-based reasoning is a problem solving paradigm that utilizes the *specific* knowledge of previously experienced, concrete problem situations (cases). A new problem is solved by finding a similar past case, reusing it in the new problem.

1. **Present:** new case or problem
2. **Retrieve**: Given a target problem, retrieve cases from memory that are relevant to solving it. A case consists of a problem, its solution, and, typically, annotations about how the solution was derived.
3. **Reuse**: Map the solution from the previous case to the target problem. This may involve adapting the solution as needed to fit the new situation. In the pancake example, Fred must adapt his retrieved solution to include the addition of blueberries.
4. **Revise**: Having mapped the previous solution to the target situation, test the new solution in the real world (or a simulation) and, if necessary, revise. Suppose Fred adapted his pancake solution by adding blueberries to the batter. After mixing, he discovers that the batter has turned blue -- an undesired effect. This suggests the following revision: delay the addition of blueberries until after the batter has been ladled into the pan.
5. **Retain**: After the solution has been successfully adapted to the target problem, store the resulting experience as a new case in memory. Fred, accordingly, records his newfound procedure for making blueberry pancakes, thereby enriching his set of stored experiences, and better preparing him for future pancake-making demands.

Simulation Model
(Joyce, Weil, & Showers, 1992)

Based on the application of cybernetic principles to education, the purpose of this model is to help students develop skills and knowledge by examining the consequences of their actions.

1. **Orientation**
   - 1.1 Present broad topic of simulation and major concepts
   - 1.2 Explain simulation and gaming
   - 1.3 Give overview of the simulation
2. **Participant Training**
   - 2.1 Set-up scenario (rules, roles, procedures, scoring, types of decisions, goals)
   - 2.2 Assign roles
   - 2.3 Hold abbreviated practice session
3. **Simulation Operations**
   - 3.1 Conduct game activity and game administration
   - 3.2 Feedback and evaluation (of performance and effects of decisions)
   - 3.3 Clarify misconceptions
   - 3.4 Continue simulation
4. **Participant Debriefing**
   - 4.1 Summarize events and perceptions
   - 4.2 Summarize difficulties and insights
   - 4.3 Analyze process
   - 4.4 Compare simulation activity to the real world
   - 4.5 Appraise and redesign the simulation

Inquiry Training Model
(Joyce, Weil, & Showers, 1992)

This model is designed to promote strategies of inquiry and the values and attitudes that are essential to an inquiring mind including: process skills (e.g., observing, collecting and organizing data), active learning, verbal expression, tolerance of ambiguity, and logical thinking.

1. **Confrontation** with the Problem
   - 1.1 Explain inquiry procedures
   - 1.2 Present discrepant event
2. **Data Gathering** - Verification
   - 2.1 Verify nature of objects and conditions
   - 2.2 Verify the occurrence of the problem situation
3. **Data Gathering** - Experimentation
   - 3.1 Isolate relevant variables
   - 3.2 Hypothesize (and test) casual relationships
4. **Organizing, Formulating and Explanation** - Formulate rules or explanations
5. **Analysis of Inquiry Process** - Analyze inquiry strategy and develop more effective ones.

Inductive-Thinking Model
(Taba, 1967)

Based on information-processing theories of human learning, the inductive-thinking model was developed to enhance students' acquisition of concepts, information processing skills as well as their convergent use of information to solve problems.

1. **Concept Formation**
   - 1.1 Enumeration and listing
   - 1.2 Grouping
   - 1.3 Labeling, Categorizing
2. **Interpretation of Data**
   - 2.1 Identify critical relationships
   - 2.2 Explore relationships
   - 2.3 Make inferences
3. **Application of Principles**
   - 3.1 Predicting consequences, explaining unfamiliar phenomena, hypothesizing
   - 3.2 Explaining and/or supporting the predictions and hypotheses
   - 3.3 Verifying predictions

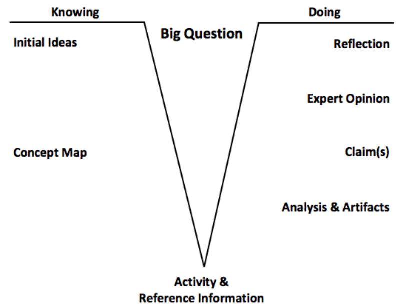
Jurisprudential Inquiry Approach
(Oliver & Shaver, 1971)

Based on Socratic modes of discussion, the purpose of this model is to help students resolve complex, controversial issues within the context of a productive social order:

1. **Orientation** to the Case
2. **Identifying** the Issues
3. **Taking** Positions
4. **Exploring** the Stance(s), patterns of argumentation
5. **Refining and Qualifying** the positions
6. **Testing** Factual Assumptions behind qualified positions

Scaffolded Vee Diagram

(Crippen, Archambault, & Kern, in press; Knaggs & Schneider, 2011)



A Scaffolded Vee Diagram serves as a guide for autonomous learning. The diagram supports students as they engage in the process of generating a scientific argument while focusing their attention on the elements of scientific knowledge (Figure 1).

Figure 1. A modified form of Gowin's Vee diagram.

1. **Big Question**. Contextualizes the inquiry and triggers motivation. Each lesson focuses on answering a big question that is based on relevant, real world problem.
2. **Initial Ideas**. Capture student ideas related to the concepts associated with the Big Question.
3. **Concept Map**. A semantic representation of student understanding.
4. **Analysis and Artifacts**. Produces a set of data in the form of an artifact that will be used in constructing a scientific claim.
5. **Claims**. Describes an evidence-claim-reason related to the big question.
6. **Expert Opinion**. Describes the scientific knowledge related to the big question.
7. **Reflection**. Analyzes and critiques how students' ideas are similar and different.

Authentic Historical Inquiry

(Waring, in press; 2011)

History is about the names, dates and events, but to spark students' interest and make connections between history and real life, instruction must shift from memorization to investigations that allow for the construction of authentic historical narratives. We must expose students to skills and knowledge in ways that are authentic and true to the methods used by professionals in the field. In other words, instead of teaching history, we should teach students how to be historians.

1. **A Hook**. Engage students with a thought provoking image, document, or other source related to the content or an activity that involves a process or concept similar to what is needed in the inquiry.
2. **Identify Fundamental Questions**. Students must have opportunities to ask and answer questions of personal interest.
3. **Engage in Primary and Secondary Sources**. A variety of sources (published or unpublished documents, oral histories, visual documents, artifacts, etc.) should be sought to answer the questions..
4. **Recognize Multiple Perspectives and Historic Causation**. Multiple alternative perspectives must be considered. Finding polar extremes or one cause for an event or one answer to the fundamental question is not sufficient.
5. **Create Plausible Narratives**. Opportunities to construct historical narratives that explain an event or answer fundamental questions utilizing the spectrum of sources, while noting where gaps in the sources or the author's knowledge exist.
6. **Assess Skills, Knowledge and Attitudes**. Consider assess plausible narratives utilizing (a) performance or product checklists, or (b) an analytic or holistic portfolio assessment rubric.
7. **Reflect on Experience**. Ask students to reflect on and share their experiences, identifying areas for future learning and investigation.

Adaptive Instructional Design
(Schwartz, Lin, Brophy & Bransford, 1992)

The primary goal of this theory is to teach a deep understanding of disciplines, while simultaneously fostering the skills of problem-solving, collaboration and communication, through the use of problem-based learning, followed by more open-ended project based learning.

1. **Look Ahead and Reflect Back**
   - 1.1 Provides an understanding of the goals, context and challenges
   - 1.2 Provides an opportunity to try it right now (pretest)
   - 1.3 Consists of motivational series of images, narrative, and questions
   - 1.4 Helps students represent a specific problem as an example of a larger set of issues
2. **Present Initial Challenge**
   - 2.1 Helps students develop a shared, initial mental model of what's to be learned
   - 2.2 Challenge selection: Motivating, interesting, invites student-generated ideas
3. **Generate Ideas**
   - 3.1 Helps students make their own thinking explicit
   - 3.2 Helps students see what other students are thinking
   - 3.3 Encourages sharing of ideas
   - 3.4 Helps teacher assess current state of student knowledge
   - 3.5 Provides students with a baseline to more easily see how much they learn
4. **Present Multiple Perspectives**
   - 4.1 Provide a way to introduce students to vocabulary and perspectives of experts
   - 4.2 Allow students to compare their ideas to experts' ideas
   - 4.3 Provide guidance on what students need to learn about
   - 4.4 Provide expertise, guidance, models of social practice in the domain
   - 4.5 Provide realistic standards of performance
   - 4.6 Indicate that multiple perspectives exist in the domain
5. **Research and Revise** (to help students explore a challenge)
   - 5.1 Consult resources
   - 5.2 Collaborate with other students
   - 5.3 Listen to "just-in-time" lectures
   - 5.4 Complete skill-building lessons
   - 5.5 Look at legacies left by other students
   - 5.6 Conduct simulations and hands-on experiments
6. **Test Your Mettle** (formative assessment)
   - 6.1 Multiple choice tests, checklists, essays, experiments, projects
   - 6.2 Feedback suggests which resources to consult to reach target
7. **Go Public**
   - 7.1 Present best solutions (oral, multimedia, print) and leave legacy of tips and ideas for future students
   - 7.2 Makes thinking visible
   - 7.3 Helps students learn to assess others and themselves
   - 7.4 Helps set standards for achievement
   - 7.5 Helps students learn from each other
   - 7.6 Motivates students to do well

Eight Events for Student Centered Learning

(Hirumi, 2002, 1998, 1996)

Based on constructivist theories of human learning, Hirumi presents seven instructional events that occur during a course to help students construct their own meaning based on their own interests and prior knowledge structures, and to promote independent, life-long learning:

1. **Set Learning Challenge** (Authentic Problem) for class
2. **Negotiate Learning Goals and Objectives** with learners
3. **Negotiate Learning Strategy** with learners
4. **Learners Construct Knowledge**
5. **Negotiate Performance Criteria** with learners
6. **Assess Learning** (Self, Peer & Expert Assessment)
7. **Provide Feedback** (Throughout Steps 1-6)
8. **Communicate Results**

Constructivist Learning

(Jonassen, 1992)

The primary goal of this theory is to foster problem-solving and conceptual development. It is intended for ill-defined or ill-structured domains.

1. **Select Problem**
   - 1.1 Problem should be interesting, relevant and engaging, to foster learner ownership
   - 1.2 Problem should be ill-defined or ill-structured
   - 1.3 Problem should be authentic (what practitioners do)
   - 1.4 Problem design addresses context, representation, and manipulation space
2. **Provide Related Cases** or worked examples to enable case-based reasoning and enhance cognitive flexibility.
3. **Provide Information**
   - 3.1 Provide learner-selectable information just-in-time
   - 3.2 Available information should be relevant and easily accessible
4. **Provide Cognitive Tools** that scaffold required skills, including problem-representation, knowledge-modeling, performance-support, and information-gathering tools
5. **Provide Conversation and Collaboration Tools** to support discourse communities, knowledge-building communities, and/or communities of learners.
6. **Provide Social/Contextual Support** for the learning environment

Additional Instructional Activities to Support Learning:

- Model the performance and the covert cognitive processes
- Coach the learner by providing motivational prompts, monitoring and regulating the learner's performance, provoking reflection, or perturbing learners' models.
- Scaffold the learner by adjusting task difficulty, restructuring the task, and/or providing alternative assessments

Teacher-Directed Approaches to Teaching and Learning

Nine Events of Instruction

(Gagne, 1974, 1977; Gagne & Medsker, 1996)

Based on information processing theories and models of human learning, Gagne posits that every unit of instruction should contain the following nine events to facilitate student learning:

1. **Gain Attention.** Use thought provoking questions, images and information to gain learners attention**.**
2. **Inform Learners of Objective(s).**
3. **Stimulate Recall** of prior knowledge to facilitate assimilation of new skills and knowledge.
4. **Present Stimulus Materials** chunking content into smaller pieces to facilitate encoding.
5. **Provide Learning Guidance** such as mnemonics, highlights and tips to facilitate interpretation, synthesis and application of content information.
6. **Elicit Performance** requiring behaviors that are aligned to objectives.
7. **Provide Feedback** about performance.
8. **Assess Performance** using methods and criteria aligned to objectives.
9. **Enhance Retention and Transfer** by asking learners to reflect on and/or apply new knowledge and skills under different conditions.

Five Learning Components

(Dick, Carey, & Carey, 2009)

To facilitate the instructional design process, Dick, Carey and Carey (2009) organized Gagne's nine events of instruction into five major learning components:

1. **Pre-instructional Activities** prior to beginning of formal instruction, addressing three factors:
   1.1 Motivating learners
   1.2 Informing learners of the objectives
   1.3 Stimulating recall of pre-requisite skills
2. **Content Presentation and Learning Guidance** explains what the unit is bout by presenting information, concepts, rules, and principles to be learned in either deductive or inductive manner. Learning guidance is integrated with content presentation using cues, outlines, diagrams, models, still and motion graphics, highlights, flowcharts, examples, etc.
3. **Learner Participation** with feedback enhances learning by giving learners an opportunity to practice what they learned using practical exercises, scenarios, and embedded tests.
4. **Assessment** including entry skills tests, pretests, practice tests, and posttest presented to learners at appropriate moments before, during or after the lesson.
5. **Follow-Through Activities** including memory aids or job aids, parallel problem scenarios, and learner plans that help learners memorize skills and facilitate the transfer of learning to new contexts.

Direct Instruction Model

(Joyce, Weil, & Showers, 1992)

Based on behaviorist theories of human learning, this model is designed to facilitate learning through stimulus-response conditioning and is said to generate and sustain motivation through pacing and reinforcement.

1. **Orientation**
   - 1.1 Establish lesson content
   - 1.2 Review previous learning
   - 1.3 Establish lesson objectives
   - 1.4 Establish lesson procedures
2. **Presentation**
   - 2.1 Explain/demonstrate new concept or skill
   - 2.2 Provide visual representation of task
   - 2.3 Check for understanding
3. **Structured Practice**
   - 3.1 Lead group through practice example in lock step
   - 3.2 Students respond to questions
   - 3.3 Provide corrective feedback for errors and reinforce correct practice
4. **Guided Practice**
   - 4.1 Students practice semi-independently
   - 4.2 Circulate, monitor student practice
   - 4.3 Provide feedback through praise, prompt, and leave
5. **Independent Practice**
   - 5.1 Students practice independently at home or in class
   - 5.2 Provide delayed feedback

Elements of

Lesson Design

(Hunter, 1990)

Widely known model for preparing lesson plans taught to pre-service teachers. Often used to evaluate lesson plans prepared by practicing educators.

1. **Anticipatory Set** – How will students' attention be focused**?**
2. **Objective and Purpose** – What will students learn and why?
3. **Input** – What new information will be discussed?
4. **Modeling** – How can teacher illustrate new skill or content?
5. **Check for Understanding** – How can teacher determine if students are learning?
6. **Guided Practice** – What opportunities are given to practice new materials?
7. **Independent Practice** – How can assignments be used for retention and transfer?

Neurobiological Approaches to Teaching and Learning

Brain Rules
(Medina, 2014)

Brain scientists have uncovered details every business leader, parent, and teacher should know—like the need for physical activity to get your brain working its best. In Brain Rules, Dr. John Medina, a molecular biologist, shares his lifelong interest in how the brain sciences might influence the way we teach our children and the way we work. He describes 12 brain rules: What scientists know about how our brains work.

SURVIVAL: The human brain evolved. The brain is a survival organ. It is designed to solve problems related to surviving in an unstable outdoor environment. The strongest brains survive, not the strongest bodies

EXERCISE: Exercise boosts brain power. The human brain evolved under conditions of almost constant motion. From this, one might predict that the optimal environment for processing information would include motion..

SLEEP: Sleep well, think well. When we're asleep, the brain is not resting at all. It is almost unbelievably active! Loss of sleep hurts attention, executive function, working memory, mood, quantitative skills, logical reasoning, and even motor dexterity.

STRESS: Stressed brains don't learn the same way. Your brain is built to deal with stress that lasts about 30 seconds. The brain is not designed for long term stress when you feel like you have no control. You can actually watch the brain shrink.

WIRING: Every brain is wired differently. What YOU do and learn in life physically changes what your brain looks like – it literally rewires it. We used to think there were 7 categories of intelligence, but may number more than 7 billion.

ATTENTION: We don't pay attention to boring things. What we pay attention to is profoundly influenced by memory. Our previous experience predicts where we should pay attention. Culture matters too.

MEMORY: Repeat to remember. The brain can only hold about seven pieces of information for less than 30 seconds! To extend the 30 seconds to a few minutes or even an hour, you will need to consistently re-expose yourself to the information.

SENSORY INTEGRATION: Stimulate more of the senses. Our senses work together! Those in multisensory environments always do better than those in unisensory environments.

VISION: Vision trumps all other senses. We are incredible at remembering pictures. Our brain sees words as lots of tiny pictures, and we have to identify certain features in the letters to be able to read them. That takes time.

MUSIC: Study or listen to boost cognition. Ideas about how music affects the brain long have been the providence of anecdote. But the research has been maturing for a while now.

GENDER: Male and female brains are different. By more than 2 to 1, women are more likely to get depressed than men, a figure that shows up just after puberty and remains stable for the next 50 years. Males exhibit more antisocial behavior.

EXPLORATION: We are powerful and natural explorers. The desire to explore never leaves us despite the classrooms and cubicles we are stuffed into. We learn, not by passive reaction to the environment but by active testing through observation, hypothesis, experiment, and conclusion.

Principles of Natural Learning
(Caine, Caine, McClintic & Klimek, 2005; Caine & Caine, 1997)

Caine and Caine (1997) conclude that, "Optimizing the use of the human brain means using the brain's infinite capacity to make connections–and understanding what conditions maximize this process." They identify three essential conditions for complex learning to occur. By addressing the 12 principles of natural learning, educators may establish the three fundamental conditions for complex learning.

1. **Relaxed Alertness**. An optimal state of mind that we call relaxed alertness, consisting of low threat and high challenge.
   a. Learning is enhanced by challenge and inhibited by threat
   b. The brain/mind is social
   c. The search for meaning is innate
   d. Emotions are critical to patterning
2. **Orchestrated Immersion**. The orchestrated immersion of the learner in multiple, complex, authentic experience.
   a. The brain/mind processes parts and wholes simultaneously
   b. All learning engages the physiology.
   c. The search for meaning occurs through patterning
   d. Learning is developmental
3. **Active Processing**. The regular, active processing of experience as the basis for making meaning.
   a. Two approaches to memory: To store isolated facts, skills, and procedures; To make sense of experience.
   b. Learning involves both focused attention and peripheral perception.
   c. Learning is both conscious and unconscious.
   d. Each brain is uniquely organized.

Interplay Strategy
(Hirumi et al., under review; Stapleton & Hirumi, 2014; Stapleton & Hirumi, 2011)

Based on the belief that the learning of facts, concepts and principles occurs best in context of how they will be used, the Interplay strategy evokes emotions and sparks imagination, based on cognitive neuroscience research, to enhance experiential learning theories by addressing three primary conventions of interactive entertainment and their related elements (i.e., Story - characters, events, worlds; Game – rules, tools, goals; Play – stimulus, response, consequences).

1. **Expose** – Exposure provides the back-story to entice empathy for the character or player, and orients the audience into the same reference point or point of view. Exposure sets up specified learning objectives in a meaningful way to invite the student to contribute, to engage and to achieve the challenges set before them.
2. **Inquire** – Inquiry validates Exposure. If exposure sets a desire to learn, then inquiry is automatic. Inquire provides a response to student's curiosity with something to do that showcases different elements that will be used later.
3. **Discover** – Discovery provides the personal reward, achievement, and the "ah ha" moment. The consequences of discovery, whether negative or positive, provide feedback to inspire further exploration to the next level of achievement.
4. **Create** – Transforms the experience from being merely reactive to truly interactive. Instead of responding to cues, the learner contributes to the content by applying the elements of the subject matter in novel ways.
5. **Experiment** – Provides an opportunity to assess learning and provide feedback without losing or winning. The goal is less about the hypothesis being right or wrong, but rather setting up the elements of the subject matter so that new knowledge can be gained. Failure should be fun.
6. **Share** – The sharing of personal experiences and feelings is facilitated at the end of the lesson or unit, to seal the memory of the learning experience. Sharing compels learners to put lessons learned in their own perspective as well as others.

Brain-Based Learning Principles

(Jensen, 2005)

Jensen posits 10 ***brain-based*** *principles that he views are most important to learning. He notes that another person might come up with a different list and still be correct and that everyone neither agrees on these principles nor on the brain-based learning strategies that can be inferred from the principles. However, these are the principles that drive Jensen's work.*

1. **Malleable memories.** Memories are often not encoded at all, encoded poorly, changed or not retrieved. Memories are susceptible to inattention, erosion over time, subject bias, misattribution and a host of other confounding conditions. Memories are strengthened by frequency, intensity and practice under varying conditions and contexts.
2. **Non-conscious experience runs automatic behaviors**. The complexity of the human body requires that we automate many behaviors. The more we automate, the less we are aware of them. Most of our behaviors have come from either "undisputed downloads" from our environment or repeated behaviors that have become automatic. This suggests potential problems and opportunities in learning.
3. **Reward and addiction dependency**. Humans have a natural craving for positive feelings, including novelty, fun, reward and personal relationships. There is a natural instinct to limit pain even if it means compromising our integrity. For complex learning to occur, students need to defer gratification and develop the capability to go without an immediate reward.
4. **Attentional Limitations**. Most people cannot pay attention very long, except during flow states, because they cannot hold much information in their short-term memory. We are born with the capacity to orient and fixate attention when it comes to contrast, movement, emotions or survival. Adapting the content to match the learner provides better attention and motivation to learn.
5. **Brain seeks and creates understanding**. The human brain is a meaning-maker and meaning seeker. We assign value and meaning to many everyday occurrences whether it's on intentional or not. Meaning-making is an important human attribute that allows us to predict and cope with experiences. The more important the meaning, the greater the attention one must pay in order to influence the content of the meaning.
6. **Rough Drafts/Gist Learning**. Brains rarely get complex learning right the first time. Instead they often sacrifice accuracy for simply developing a "rough draft" of the learning material. If, over time, the learning material maintains or increases in its importance and relevance, the brain will upgrade the rough draft to improve meaning and accuracy. To this end, prior knowledge changes how the brain organizes new information. Goal-driven learning proceeds more rapidly than random learning. Learning is enhanced by brain mechanisms with contrasting output and input goals.
7. **Input Limitations**. Several physical structures and processes limit one's ability to take in continuous new learning. The "slow down" mechanisms include the working memory, the synaptic formation time for complex encoding and the hippocampus. While we can expose our brain to a great deal of information in a short time frame, the quality of that exposure is known as "priming" and is not considered in-depth learning. Schools typically try to cram as much content as possible in a day as possible. You can teach faster, but students will just forget faster.
8. **Perception influences our experience**. A person's experience of life is highly subjective. Many studies show how people are easily influenced to change how we see and what we hear, feel, smell and taste. This subjectivity alters experience, which alters perception. When a person changes the way they perceive the world, they alter their experience. It is experience that drives change in the brain.
9. **Malleability/Neural Plasticity**. The brain changes every day and more importantly, we influence those changes. New areas of brain plasticity and overall malleability are regularly discovered. It is known that experience can drive physical changes in the sensory cortex, frontal lobes, temporal lobes, amygdala and hippocampus. In addition whole systems can adapt to experience such as the reward system or stress response system.
10. **Emotional-Physical State Dependency**. Nearly every type of learning includes a "go" or "no go" command to the brain in our neural net signaling process. These complex signals are comprised of excite or suppress signals. Emotions can provide the brain's signals to either move ahead or not. Thus, learning occurs through a complex set of continuous signals which inform your brain about whether to form a memory or not. Both emotional and bodily states influence our attention, memory, learning, meaning and behavior through these signaling systems.

Alternative Approaches to Teaching and Learning

4Mat System Model

(McCarthy, 1987)

Based on research and literature on learning styles, this eight-step cycle of instruction is meant to capitalize on students' learning styles and brain dominance processing strengths. Rather than focus on one learning style, this method encourages students to examine and experience all learning styles.

1. **Create** an experience
2. **Reflect/Analyze** Experience
3. **Integrate** reflective analysis into concepts
4. **Develop** concepts/skills
5. **Practice** defined "givens"
6. **Practice** adding something of oneself
7. **Analyze** application for relevance, usefulness
8. **Apply** to new more complex experience

SQR Model

(Maier, 1990)

This strategy is designed to encourage students' to take responsibility for their learning and to give students a way to generate their own ideas. In general, this strategy is geared toward enhancing student learning from reading, but may be applied in other context.

1. **Summarize**
   - 1.1 Read materials
   - 1.2 Write a summary of the materials in journal
2. **Question**
   - 2.1 Write question on the materials in journal
   - 2.2 Discuss summaries and questions in small group
   - 2.3 Select "best" question to share with whole class based on ability to provoke engaging discussions
   - 2.4 Discuss "best" questions with whole class utilizing questioning techniques
3. **Response** - Write a response to the small group or whole group class discussion (summary of main points)

SQ3R Study Strategy

(Robinson, 1961)

This strategy is designed to help students develop their study skills, particularly in relation to reading assignments.

1. **Survey** - Readers preview materials to develop general outline for organizing information.
2. **Question** - Reader raises questions with expectation of finding answers in materials
3. **Read** - Reader attempts to answer questions by reading
4. **Recite** - Reader answers questions out loud or in writing
5. **Review** - Reader rereads portions of materials to verify answers given during previous step

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