ISTE Workshop

Research Methods in Educational Technology

IIT Bombay
February 2-9, 2013
Research Study Presentation

by

Mrinal Patwardhan

Faculty at D. J. Sanghvi College of Engineering (Mumbai)

and

Educational Technology Research student at IITB (Under guidance of Prof. Sahana Murthy)
Are my students learning?

Can something be done to improve their learning?

What can be done to improve their learning?
Are my students learning?

Can something be done to improve their learning?

What can be done to improve their learning?

ET practitioner → ET researcher
What is the problem I am trying to address?
Engineering Curriculum caters to numerous concepts, processes, procedures, principles

......from Ohm’s law to field equations, IV characteristic of PN diode to VLSI chip designing .....
Engineering Curriculum caters to numerous concepts, processes, procedures, principles.

Addresses varying difficulty level of content, ..... simple to abstract concepts and from understanding to designing aspects......

.....from preparing truth table for a logic gate to designing a single board system in embedded system design....
Engineering Curriculum caters to numerous concepts, processes, procedures, principles.

Addresses varying difficulty level of content, simple to abstract concepts and from understanding to designing aspects.

Interactive visualizations in engineering education have proven to be beneficial.
Especially beneficial for learning scientific concepts, processes, principles
Especially beneficial for learning scientific concepts, processes, principles

Being considered as one of the important instructional strategies for achieving effective learning
Especially beneficial for learning scientific concepts, processes, principles

Being considered as one of the important instructional strategies for achieving effective learning

Can interactive visualizations be of my use in teaching – learning process?
My experience while teaching ‘Signals and Systems’

• Students often find it difficult to visualize time domain and frequency domain of a signal

• How does any operation on signal in time domain affect its frequency domain?

• Some obstacles while learning the course …. various transforms and their properties, process of convolution, Fourier analysis of signals (signals synthesis and analysis)
• Unfortunately, many times ‘Signals and Systems’ is considered as just one more course on abstract mathematics whereas it needs to be considered as a foundation course to delve deeper into signals & signal processing.
• Can interactive visualizations help students in understanding such fundamental concepts?

• Can the use of interactive visualizations while learning ‘Signals and Systems’ give more insight about the course contents?

• However, though interactive visualizations are beneficial, there is inconsistency in the results reported in literature …….
How do I know ‘when and which’ interactive visualizations will lead to effective learning?

Will interactive visualization promote effective learning for all levels of learning?
Will interactive visualization promote effective learning for all levels of learning?

Answering this question will allow me ensure effective learning from interactive visualizations in the domain of ‘Signals & Systems’.

Why is my problem important?
What is my idea?
(What solution I proposed ?)
Identify potential topics

Interactive visualizations
Interactive visualizations

Identify potential topics

Identify / develop interactive visualizations
Interactive visualizations

Identify potential topics

Identify / develop interactive visualizations

Develop assessment tool
Interactive visualizations

Identify potential topics

Identify / develop interactive visualizations

Develop assessment tool, give treatment

Analyze the learning impact
Interactive visualizations

Identify potential topics

Identify / develop interactive visualizations

Develop assessment tool, give treatment

Analyze the learning impact

2/11/2013
Development of engineering design skills
Interactive visualizations

Identify potential topics

Identify / develop interactive visualizations

Develop assessment tool, give treatment

Analyze the learning impact

My idea
Is my idea novel?
• Learning happens at different levels…. Cognitive efforts needed for ‘remembering a formula’ are different than while ‘designing a Decade counter’ or while ‘solving a differential equation’.
Learning happens at different levels....

Cognitive efforts needed for remembering a formula’ are different than while ‘designing a Decade counter’ or while ‘solving a differential equation’.

Interactive visualizations with differing levels of interactivity offer varying learning experience to users.
Learning happens at different levels.... Cognitive efforts needed for remembering a formula’ are different than while ‘designing a Decade counter’ or while ‘solving a differential equation’.

Interactive visualizations with differing levels of interactivity offer varying learning experience to users.

Thus, different ‘kinds of visualizations’ will offer effective learning while learning different ‘kinds of learning tasks’ and different ‘kinds of knowledge types’.
How do I position my idea?
• Literature review (Prior work)
  – Different cognitive levels … Bloom’s Taxonomy

  – Different knowledge types

  – Different levels of interactivity in visualization
• Literature review (Prior work)
  – Different cognitive levels … Bloom’s Taxonomy
  – Different knowledge types
  – Different levels of interactivity in visualization
  – Signals and Systems Education Research

All this in the context of ‘Signals and Systems’
• Literature review (Prior work)
  – Different cognitive levels … Bloom’s Taxonomy
  – Different knowledge types
  – Different levels of interactivity in visualization
  – Signals and Systems Education Research

All this in the context of ‘Signals and Systems’
How did I implement my idea using a systematic procedure?
Identify topic

Define learning objectives

Establish suitability of visualization for the given learning objectives

Identify / develop interactive visualization
Finalize research design → Develop assessment test instrument

Identify sample → Establish validity of the developed instrument
Establish group equivalence

Give treatment

Answer the RQ: Did the solution work?

Analyze results
Developing soundness with support from relevant learning theories and literature

• When to use interactive visualizations?

• Signals and Systems content analysis and education research

• Multimedia principles for effective learning

• Varying levels of interactivity in visualizations and its impact on cognitive engagement on students
How do I know my idea is working?
Setting up research experiment

- **Plan**
  - Research Design Details

- **Implement**
  - Treatment

- **Analyze**
  - Statistical Analysis of results
How much careful you are in the planning stage of your research experiment, will directly decide the success of your research experiment.
Anticipate and consider all the confounding variables in your study, look for their solutions in the planning stage itself rather than dealing with them after you are done with the experiment.
- Spend sufficient amount of qualitative time while planning for your experiment.
Planning for the experiment
Research design details

Experiment details

• Variables:
  – Independent variable
    – Visualizations with different level of interactivity (e.g. animation and variable manipulation)
  – Dependent variable
    – Test score in assessment test
Planning for the experiment
Research design details

• Research Design:
  Two group; Pre-test and post-test design

• Sample:
  • Third year engineering students
Planning for the experiment
Research design details

• The students were divided into two random groups wherein they would be learning the same content from interactive visualizations with different interactivity level ‘A’ and ‘B’.

• Test instrument was developed to assess students’ learning from visualization in the selected knowledge domain.
Implementing the research experiment

The research design implementation

Group 1 → Pre-test → Treatment
Learning from visualization (animation) → Post-test

Group 2 → Pre-test → Treatment
Learning from visualization (with variable manipulation) → Post-test
Implementing the research experiment

Both the groups were given pre-test initially to judge student’s knowledge in the given topic (Graphical interpretation of Convolution)
Implementing the research experiment

Both the groups were given pre-test initially to judge student’s knowledge in the given topic (Graphical interpretation of Convolution).

The groups were given treatment. One group learnt the topic from animation, whereas the other group learnt from an interactive visualization with variable manipulation.
Implementing the research experiment

Both the groups were given pre-test initially to judge student’s knowledge in the given topic (Graphical interpretation of Convolution).

The groups were given treatment. One group learnt the topic from animation, whereas the other group learnt from an interactive visualization with variable manipulation.

The learning impact of treatment was judged by conducting a post test.
What all did I have to worry about?
How to select students for study?

Group formation

• Students undergoing a course on ‘Signals and Systems’; unfamiliar with the topic

• Group equivalence with respect to their academic performance
  
  e.g. the groups selected were matched random assignment groups with their academic score averages as 547.55 and 549.17

• Group matching with respect to gender issue.
Is my visualization selection appropriate keeping in mind the learning objectives?

- The visualizations selected / created were validated by domain experts to check its appropriateness for the designed learning objectives.

- The usability study conducted for the selected visualization established its usability aspect.
Is my assessment tool measuring what I intend to?

- The topics selected were from Signals and Systems.
Is my assessment tool measuring what I intend to?

- The topics selected were from Signals and Systems.

- The learning objective set were addressing different cognitive levels; such as ‘apply’, ‘understand’ and different content types; such as ‘concept’, ‘process’.
Is my assessment tool measuring what I intend to?

- The assessment instrument developed had questions addressing to these different cognitive levels and different content types.
Is my assessment tool measuring what I intend to?

The assessment instrument developed had questions addressing to these different cognitive levels and different content types.

This assessment instrument was validated by domain experts and ET experts to establish its validity.
Is my assessment tool measuring what I intend to?

The assessment instrument developed had questions addressing to these different cognitive levels and different content types.

This assessment instrument was validated by domain experts and ET experts to establish its validity.

The relevant feedback given by experts was used for modifying the assessment instrument to establish its validity.
1. \( x(t) \) is a signal and \( y(t) \) is its transformed version. Identify which transformation operation has been carried out on \( x(t) \) so as to get \( y(t) \).

- a. time shifting
- b. time scaling
- c. time reversal
- d. none of the above

**Understand Process**

8. Identify which of the following is the correct mathematical representation of the signal transformation on signal \( x(t) \) so as to get \( y(t) \).

- a. \( y(t) = \frac{3}{2}t + 1 \)
- b. \( y(t) = x\left(\frac{2}{3}t + 1\right) \)
- c. \( y(t) = x(3t + 2) \)
- d. \( y(t) = x\left(-\frac{3}{2}t + 1\right) \)

**Apply concept:**

3. Calculate by how many units the signal \( x(t) \) has been time scaled so as to get signal \( y(t) \).

- a. \( \frac{1}{2} \)
- b. 1
- c. 2
- d. None of the above

6. If \( x(t) \) and \( h(t) \) of a system are as shown, plot \( y(t) \) by using graphical convolution method.
Transformation of Continuous Time Signal

Time Scaling (Compressing)

\[ Y = X(t) \]

\[ Y = 0.01 \times X(2.16t + 1.76) \]

Compressing by \( X(2.16t) \)
Please select the signal by clicking on the signal images on the right side.

\[ y(t) = \int_{-\infty}^{\infty} f(\tau)g(t-\tau) \, d\tau \]

Explanation:
- The signal \( f(t) \) is shown.
- The reversed and shifted version of \( g(-t) \) is shown.
- \( g(t-1) \) completely overlaps \( f(t) \) for \( 0 \leq t \leq 1 \).
  \[ g(t) = 1 \]
  \[ f(t) = e^t \] for \( 0 \leq t \leq 2 \)
How I collected and analyzed data?
Implementing the research experiment

The research design identified was implemented

Group 1 → Pre-test → Treatment
Learning from visualization (animation) → Post-test

Calculate the learning gain

Group 2 → Pre-test → Treatment
Learning from visualization (with variable manipulation) → Post-test
Implementing the research experiment

The research design identified was implemented

Group 1  →  Pre-test  →  Treatment  
Learning from visualization (animation)  →  Post-test

Average learning gain with animation

Group 2  →  Pre-test  →  Treatment  
Learning from visualization (with variable manipulation)  →  Post-test

Average learning gain with variable manipulation

09/02/2013
Interactive Visualizations in Engineering Education
How did I know which group perform better?
Analyze: Statistical analysis of results

The learning gain average was compared for both the groups; separately for assessment question belonging to different cognitive levels.
Analyze: Statistical analysis of results

The learning gain average was compared for both the groups; separately for assessment question belonging to different cognitive levels.

Did the treatment work?

– ‘Paired sample t test’ was used to compare statistical significance of the difference (learning gain) between post-test and pre-test scores.
Analyze: Statistical analysis of results

The learning gain average was compared for both the groups; separately for assessment question belonging to different cognitive levels.

Did the treatment work?
- ‘Paired sample t test’ was used to compare statistical significance of the difference (learning gain) between post-test and pre-test scores.

Which treatment worked better?
- ‘Independent sample t test’ was used for comparing learning gain averages of both the groups.
# ANCOVA result analysis

<table>
<thead>
<tr>
<th></th>
<th>Gr. I - ILO</th>
<th>Gr. II - ILO</th>
<th>Gr. I – IL1</th>
<th>Gr. II – IL3</th>
<th>P value from ANCOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>UP</td>
<td>3.239</td>
<td>2.29</td>
<td>3.563</td>
<td>3.18</td>
<td>0.266</td>
</tr>
<tr>
<td>AP</td>
<td>1.493</td>
<td>1.00</td>
<td>8.423</td>
<td>8.90</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Result presentation

AP – Apply Process
UP – Understand Process
IL1 – Animation
IL3 – Visualization with variable manipulation

Interactive Visualizations in Engineering Education

09/02/2013
Result presentation

AP – Apply Process
UP – Understand Process
IL1 – Animation
IL3 – Visualization with variable manipulation

Non-equivalent Group Design
Summary of result

• ‘Apply level’ cognitive tasks for the ‘process’ content type require visualizations with variable manipulation for effective learning in the given domain area.

• Students learning with visualizations with variable manipulation for apply process cognitive task performed better than students learning from animation.
Summary of result

For Understand level cognitive tasks for the process content type, effective learning can be achieved by using visualization in the form of animation in the given domain area.

• For understand process level cognitive task, students’ performance with visualization with variable manipulation and animation was found to be statistically same.
Did my idea really work?
My idea was to use interactive visualization to achieve effective learning while dealing with abstract concepts in the domain of Signals and Systems; keeping in mind the cognitive level and content type of the task.
• My idea was to use interactive visualization to achieve effective learning while dealing with abstract concepts in the domain of Signals and Systems; keeping in mind the cognitive level and content type of the task.

• Results show that for different amount of interactivity in visualization would assure effective learning while catering to different kinds of tasks; suggesting higher level of interactivity for higher cognitive level for the selected topic.

• These results contribute towards ensuring effective learning from interactive visualizations.