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CuVIS Tool to Develop Instructors' Competency in Creating Meaningful Learning Designs

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Abstract: Visualizations are effective teaching-learning resource. But their effectiveness is undermined if the instructor simply lectures with the tool. Such ineffective integration of visualization persists in spite of existing teaching guidelines, teacher training workshops, portals for sharing best practices and learning design (LD) tools. In fact, the problem gets compounded at the tertiary level where visualization integration is left to individual instructors. In the current paper, we present the Customized Visualization Integration (CuVIS) tool targeted at college instructors teaching in instructor-mediated classrooms. Such classrooms were chosen since they are the norm in colleges in India and the developing world. CuVIS takes objective, activity time requirements and domain as instructor inputs and outputs a LD customized to the instructor's context. A semester-long study with a cohort of 4 instructors across 3 time points was conducted. We found CuVIS use led to increase in instructors' TPACK in terms of their competency in designing student-centered LDs with visualization. Analysis of these LDs revealed CuVIS scaffolding was successful in veering instructors towards creating theory-informed LDs aligned to their instructional objective and the 5 dimensions of Meaningful Learning. This paper also contributes to LD research by identifying points in the LD process where instructors required help and the scaffolds that successfully addressed the difficulties. CuVIS is also a valuable training resource for teacher educators at the tertiary level.

Keywords: Learning design, Visualization, Meaningful Learning, Alignment, TPACK

1. Introduction

Well-designed visualizations have proven potential to improve learning outcome for students (Rutten et al., 2012). However, lecturing with ICT tools like visualizations has been found to be the predominant instructional strategy used across educational levels (Angeli & Valanides, 2009). Such information transmission strategy undermines the learning effectiveness of visualizations. It points to the need for developing instructors' knowledge of how to teach with technological tools (Angeli & Valanides, 2009). This knowledge pertains to a blend of their technological, pedagogical and content knowledge (TPACK) (Mishra & Koehler, 2006). Multiple solutions have been proposed to assist instructors to develop their TPACK in planning effective and meaningful integration of ICT tools. These include teacher training programs and workshops, online portals for sharing best practices, teaching guidelines and learning design tools. However, the problem of ineffective integration of ICT tools continues (Laurillard, 2012; Bennett et al., 2015). This problem is compounded for instructors at the tertiary level. At this level, the content topics become more abstract (Coppola & Krajcik, 2014) requiring deeper and broader expertise. The instructional objectives are focused on equipping students to transition from academic to professional world (Coppola & Krajcik, 2014; Bennett et.al, 2015). Thus with content knowledge (CK) becoming complex, TPACK becomes more challenging. Additionally, college instructors have neither the required support nor time to translate the existing pedagogical theory into practice (Laurillard, 2012). Besides, majority of the studies on ICT integration has been conducted in the context of K-12 classrooms and their results may not be transferable to classrooms at the tertiary level (Bennett et al., 2015). The setting of instructor-mediated classrooms, which are the norm in colleges in India as well as in many developing countries, pose an additional challenge to instructors in creating student-centered LDs (Banerjee et al., in press). This is because in such classrooms student interaction with the visualization is routed via the instructor with students not having access to individual laptops.

As a solution to the above problem we developed the Customized Visualization Integration (CuVIS) tool. CuVIS aims to scaffold college instructors to create effective and meaningful LDs with their chosen visualization for instructor-mediated classrooms. We define visualization (video/ animation/ simulation) as "the use of computer supported, interactive, visual representations of data to amplify cognition" (Tory & Moller, 2004). The CuVIS tool captures the variation in instructors' domain; objective and activity time requirements and assists them in creating a theory-informed, research-based LD customized to their requirements. The tool is founded on the teaching principles of Constructive Alignment (Biggs, 1996) and Meaningful Learning with ICT (Howland et al., 2012). Hence, CuVIS LDs are aligned to the instructional objectives as well as incorporate the 5 dimensions of Meaningful Learning - Active learning, Constructive, Authentic, Intentional and Cooperative (Howland et.al, 2012). The tool takes the instructor's objective and activity time specifications as input. Accordingly, it suggests a possible active learning strategy along with its implementation methodology. It then scaffolds the instructor through a series of 'Activity Constructor' prompts mapped to their domain as also strategy and objective. Additionally, the prompts guide the instructors on exploiting relevant visualization affordances to design learning activities with the tool.

In this paper, we present a semester-long study with 4 in-service Engineering instructors who used CuVIS to create student-centered LDs for their specific objective and time requirements. The study tracks instructors' TPACK levels in terms of their competency in designing meaningful LDs with visualization across 3 time points – before (no scaffold, pretest), after (using CuVIS scaffold, post-test) and 3-4 months after withdrawal of CuVIS (no scaffold, transfer). We found use of CuVIS led to increase in TPACK in transfer phase along all the dimensions of Meaningful Learning and Alignment. All instructors migrated from lecturing with visualization to doing a series of student-centered activities based on the visualization. CuVIS was able to expand instructors' knowledge of teaching principles as also their ability to translate them into practice.

This study contributes to LD research by identifying points in the LD creation process where instructors need help and the type of scaffold that can address those difficulties. It also provides empirical evidence of the effectiveness of these scaffolds. CuVIS serves as a valuable training resource for teacher-educators to cement instructor's learning from the training programs. Instructors benefit from CuVIS use through improvement in their TPACK for designing meaningful and aligned LDs. The tool provides a solution to mitigate the current problem of ineffective integration of visualizations.

2. Related Work for Scaffolding Visualization Integration

Teaching with technological tools like visualizations places new demands on today's instructors. To achieve effective, student-centered integration of visualizations, instructors need to develop their TPACK (Mishra & Koehler, 2006). TPACK represents the synthesis of their content as well as technological and pedagogical knowledge. Angeli & Valanides (2009) stressed that in addition to TPACK constructs, instructors' also need to incorporate knowledge about their own context and their learners to make teaching with ICT effective. Taxonomies like Taxonomy of engagement levels with visualization (Naps et.al, 2002) or Extended Engagement Taxonomy (Myller et.al, 2009) have classified student engagement with visualizations into multiple levels. They hypothesize that learning and collaboration among students increases with increase in engagement level like 'Viewing' (passively) to 'Responding' (responding to activity questions on visualization content). Besides, teaching principles like Constructive Alignment (Biggs, 1996) asserts that the assessment and learning activity should map to the learning objective. The principle of Meaningful Learning with ICT (Howland et al., 2012) states that to ensure the learning activity is student-centered it must include the dimensions of Active learning, Constructive, Authentic, Intentional and Cooperative. But this knowledge set is difficult for instructors to translate into practice (Laurillard, 2012). Various online portals like COSMOS, AlgoViz (Shaffer et. al., 2011) have been developed. They support instructors by sharing best practices that operationalized the theoretical knowledge into practice. However, the best practices are specific instantiations and instructors face problems in adapting them to their own context (Shaffer et al., 2011). Teacher training programs assist instructors in bridging the gap from theory to practice. But, the long-term training programs are mostly at school level (Bennett et al., 2015). At tertiary level short, in-service training workshops exist but they are insufficient to enable instructors to create effective LDs (Conole & Alevizou, 2010).

An emerging solution for tertiary education are LD tools like Learning Designer (Laurillard et.al., 2013) that support college instructors in designing effective learning activities with ICT tools. LD is defined as "a methodology for enabling teachers/designers to make more informed decisions in how they go about designing learning activities and interventions, which is pedagogically informed and makes effective use of appropriate resources and technologies. This includes the design of resources and individual learning activities right up to curriculum-level design." (Conole, 2012). Current LD research is seeking to answer questions on what influences instructors' design decisions, at what points in the LD creation process do they need scaffolding and what should be the features of such scaffolding (Bennett et.al., 2015). Research has come up with design recommendations for LD tools (Laurillard et.al, 2013; Bennett et.al, 2015). The recommendations include tools that accommodate domain influences, are flexible for instructors to customize as well as accommodate changes 'within the design', and are a balance between open-ended, unsupported design and rigid templates (Bennett et.al, 2015). Laurillard et.al. (2013) has identified additional tool features like links to existing LDs and research findings, a stepwise default design process, evaluation feedback on the LD created and Constructive Alignment at the granularity of individual objectives (Boyle, 2010). Empirical studies are required to test the impact of these recommendations on instructors' design practice as also extend the theoretical and practical knowledge of LDs (Bennett et.al, 2015). The current study aims to contribute to LD research by expanding knowledge about stages in the LD creation process where instructors need scaffolding and what types of scaffold will be effective for the purpose. It also presents empirical evidence of the impact of these scaffolds on instructors' TPACK in terms of their competency in planning visualization integration in instructor-mediated classrooms.

3. CuVIS Tool for Learning Design

3.1 Functioning of CuVIS tool

CuVIS scaffolds instructors in creating effective and meaningful LDs with their chosen visualization in context of instructor-mediated classrooms (Fig.1). CuVIS is based on the principles of Constructive Alignment (Biggs, 1996) which demands that CuVIS LDs are aligned to instructor's objective. CuVIS is also based on Meaningful Learning with ICT (Howland et al., 2012), and incorporates the 5 dimensions of Meaningful Learning. Students use the ICT tool to - a) actively engage with its content (Active learning), b) construct their own knowledge through self-reflection and articulation (Constructive), c) devise solutions to real-life problems (Authentic), d) set their learning goals, evaluate their understanding and self-diagnose their errors (Intentional) and e) do group activity with their peers (Cooperative).

CuVIS guides instructors through a sequence of steps based on the Analysis and Design stages of the ADDIE model of instructional design. It provides scaffolding at three points in this process:

i) Choosing an active learning strategy mapped to their objective and learning activity time requirement. The strategy should have been used successfully with visualization in a classroom setting in prior empirical studies. It should also support Meaningful Learning with ICT (Fig. 1).
ii) Guiding the instructor stepwise through the LD creation process via a set of 'Activity Constructor' prompts. These prompts scaffold instructors in designing LD that is aligned to their objective and Meaningful Learning with ICT. For example, the prompts provide guidelines on framing activity questions (Formative assessment) mapped to objective. To help them translate the guidelines into practice, each prompt is accompanied with illustrative examples from the instructor's domain (Fig. 2). Currently, the examples are scoped to the domains of Electrical and Computer Engineering.
iii) Sequencing instructors' responses to the prompts as per implementation methodology of the suggested strategy in the LD blueprint. The editable blueprint has flexibility for the instructor to modify the final LD as per their choice. Thus, the final LD contains full implementation plan structured into steps with specified time duration, instructor and student roles and visualization affordance to be used at each step. It also informs the instructor on how dimensions of alignment and Meaningful Learning have been operationalized in the LD. It is thus a best practice example generated from the instructor's own requirements and responses to the prompts. An important feature of CuVIS tool is the variation in instructor requirements it is able to capture. The content of each scaffold differs depending on the input combination of instructional objective, domain and activity time requirements (Fig.2).

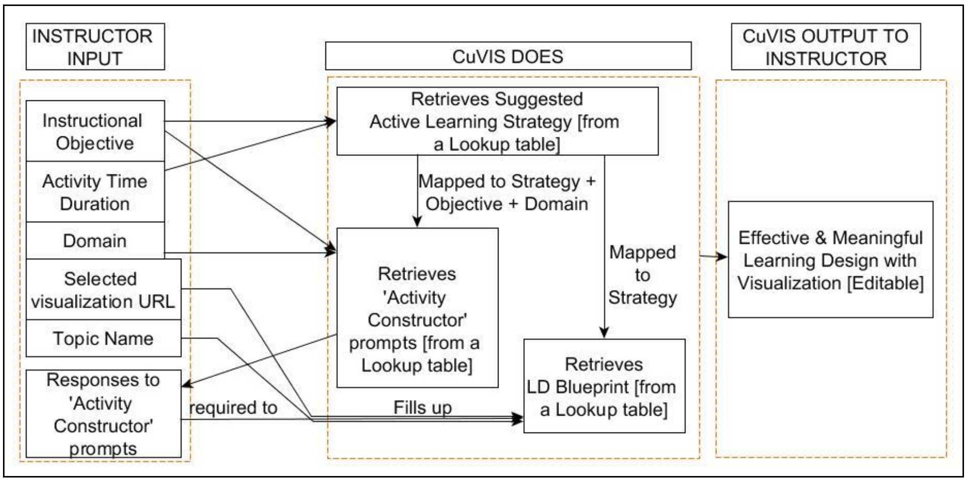

Figure 1. Function of CuVIS tool.

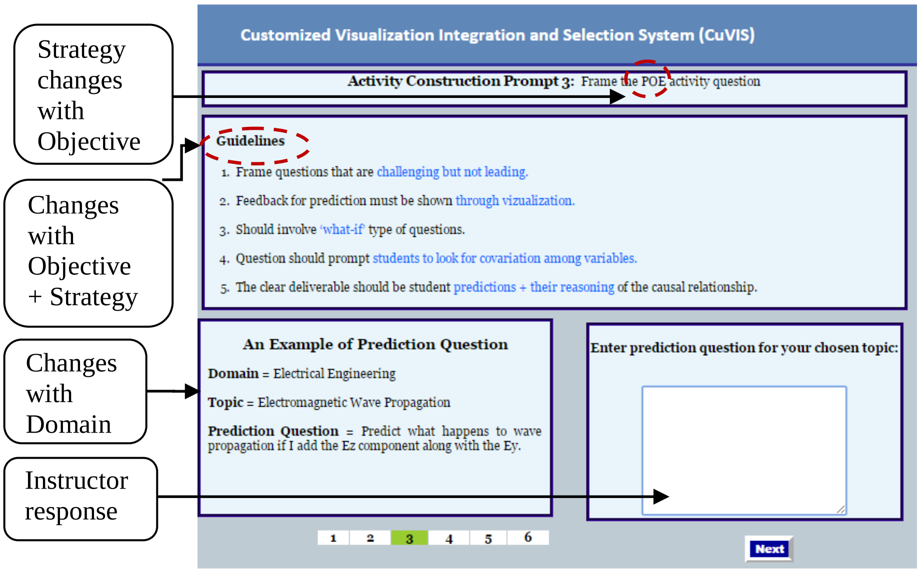

Figure 2. Example screenshot of an 'Activity Constructor' prompt in CuVIS.

3.2 Building the CuVIS tool

CuVIS tool was developed following iterative cycles of Design and Development Research (DDR) methodology. DDR proceeds through the phases of Preliminary Research, Design and Development, and Evaluation (Van den Akker et al., 2006). Feedback from target users i.e. in-service Engineering instructors was taken at every phase to enhance the practical utility of the product in real-life scenario. In this section we present an overview of the first two phases of the DDR methodology followed with details of the Evaluation phase in Section 4. In the 'Preliminary Research' phase, the first step was identification of instructional objectives with visualization from analysis of 61 instructor interviews (Banerjee et al., 2014). We identified a superset of 6 objectives like Predict outcome of a phenomenon or a multi-step process or Write/Draw alternate representation from the given visualization or Use visualization to compute solution to the given problem involving multiple processes.

The next step involved deciding on the content for each scaffold. We identified research-based active learning strategies that have been used successfully with visualization in a classroom setting for each of the identified objective. Further the shortlisted strategies for each objective were sorted based on the total time required for its effective execution. This was done from analysis of literature on empirical studies of teaching with visualization in classroom setting. The guidelines of the 'Activity Constructor' prompts were synthesized from results of systematic analysis of literature on learning and cognitive studies related to attainment of the objective. For this the research databases of ERIC and

SCOPUS were surveyed. The selection criteria were papers from the last 10 years, related to cognitive process of attainment of the objective. We also looked at cross-referenced papers as well as papers on supports, both pedagogical and technological, for that objective, if any.

In the Design and Development phase, the outputs from the above steps were translated to the design of CuVIS scaffolds (Table 1). The sequencing of the scaffolds within CuVIS was based on the ADDIE model. For example, the Content Analysis prompt of 'Decide how to connect the topic to real-life' comes before the Activity Design prompt of 'Frame the activity question'. The design of the LD blueprint was mapped to the implementation methodology specific to the particular strategy as specified in literature. The final CuVIS tool was created after four cycles of feedback iterations with the target users in terms of usefulness and usability.

Table 1: Example of theory translated into design of CuVIS scaffold for a particular objective

Instructional Objective	Cognitive process of objective	Designing support	Translated into CuVIS guidelines as:
Predict outcome of a phenomenon or a multi-step process using the visualization	a) Identifying causal variables (Jonassen & Ionas, 2008)	Observe multiple condition sets through variable manipulation (Jonassen & Ionas, 2008)	Frame an activity question that covers multiple condition sets (Fig. 2)
	b) Identifying model of the relationship (Jonassen & Ionas, 2008; Gunstone & Mitshell, 1997)	Question prompts help in understanding the model of the relationship (Jonassen & Ionas, 2008)	Ask guiding questions like: i) What was the most direct cause of the bulb blowing up? ii) Why is printf statement showing an increased value of variable y?

4. Research Design

4.1 Research questions

The current study is focused on evaluating the effectiveness of the CuVIS tool. Effectiveness of CuVIS assisted LDs on student learning has been established in prior studies (Banerjee et al., in press; Banerjee et al., 2014). In this paper, we focus on effectiveness of CuVIS in improving instructors' TPACK for designing learning activities with visualization. We also study the impact of CuVIS on 'sequence of activities' designed in the LD. Sequence of activities is defined as detailed description of all teaching activities that form part of the teaching method along with their temporal sequence (Laurillard & Ljubojevic, 2011). This is the crucial part of a LD that captures the pedagogical practice of the instructors (Laurillard, 2012). Thus, the research questions of this study were:

- RQ 1: How effective is CuVIS in improving instructors' TPACK in terms of creating effective, meaningful and customized learning designs with visualization?
- RQ 2: What is the impact of CuVIS on sequence of activities in the LD?
- RQ 3: What features should a scaffold have to enable instructors to develop their TPACK for effective and meaningful visualization integration?

4.2 Participants

The participants of the study were Electrical and Computer Engineering instructors who had attended a 2-week blended pedagogy workshop (Murthy et al., in press), prior to this study. Thus they were exposed to various constructivist teaching strategies like Peer Instruction and, Think-Pair-Share. Ten instructors volunteered out of which 4 instructors (Female = 3, Male = 1) completed the study to date. The average teaching experience was 12 years and their age was in the range of 35 - 45 years. Two instructors were from small towns and the other two were from large cities. They have taught UG level courses with visualizations in medium-sized instructor-mediated classrooms of 70 – 100 students.

4.3 Procedure

As part of the third phase of DDR methodology, CuVIS scaffolding was tested for effectiveness in a semester-long study spanning six months. A cohort of four Engineering instructors was tracked at three different time points. At the first time point, they developed a LD with visualization for their chosen objective without CuVIS. In the second time point, they used the CuVIS tool to generate a LD. This LD incorporated 5 dimensions of Meaningful Learning and was mapped to their objective and time requirements. It also contained explicit pointers to how each of the dimensions has been operationalized within the LD. The time interval between the second and third time points was 3-4 months on average. At the third time point, the instructors generated another LD but without CuVIS scaffolds. They were provided with a checklist to make them recall the dimensions of Meaningful Learning and alignment that needed to be incorporated. Across the time points the topic varied to avoid the threat of maturity but the instructional objective remained constant. The chosen visualizations included videos, animations and simulations. The LD produced at the first time point was treated as pre-test, the second LD generated with CuVIS was taken as post-test and the third LD was evaluated for transfer of competency in designing effective and meaningful learning activities with visualization. Since LDs are a reflection of the instructors' TPACK (Koh, 2013), they were evaluated with a rubric to measure instructors' TPACK levels at each time point.

4.4 Data analysis technique

Two data sources were used – the LDs produced by each instructor at each time point and their interviews post the study. The LDs produced by each instructor were evaluated along two axes. Along one axis, they were evaluated to track instructors' TPACK in terms of their competency in designing meaningful learning activities. The TPACK rubric by Koh (2013) with a grading scale of 0-4 was chosen for this purpose. This rubric was chosen because each of its criteria represented each dimension of Meaningful Learning. Also validity of the rubric has been established. We added the Alignment criteria to this rubric. These criteria measured if all the alignment guidelines have been operationalized through proper implementation of an active learning strategy. The inter-rater reliability of this rubric was found to be Cohen's kappa = 0.81.

The other axis was tracking the evolution of the sequence of activities in the LD through time allocation analysis methodology, adopted from Kong et al., (2011). Content analysis of the twelve (4x3) LDs was done to identify various categories of teaching activities designed. For each instructor, the variation in time allocation for each category was recorded. The percentage of allocated time gives a measure of effectiveness of CuVIS in terms of degree of student engagement and the extent of student-teacher dialog (Kong et al., 2011). Thematic analysis of instructors' semi-structured interviews were done to understand their design experience with the CuVIS tool. Each instructor was interviewed twice – after the post-test and transfer phases for 15-20 minutes. The interview transcripts were analyzed through the 6-step thematic analysis methodology (Braun & Clarke, 2006). Thematic analysis was chosen since the objective was to understand the impediments instructors face in the design process and how successful CuVIS has been in resolving them.

5. Results

5.1 Assessment of TPACK for meaningful & effective learning with ICT

The LDs produced by each instructor at each time point were evaluated for the instructor's TPACK. Analysis of the total TPACK scores (Fig. 3) shows that CuVIS use resulted in increase in TPACK levels for all the instructors. They were able to retain their higher TPACK levels in the Transfer phase, even after withdrawal of CuVIS scaffolding. The scores in the Transfer phase for all the instructors were in the range of 20-23 out of 24. An instructor-wise analysis of scores (Fig. 4) helped us identify the impact of CuVIS along each of the rubric criteria. We found CuVIS use increased scores along Constructive, Intentional, Cooperative and Alignment dimensions for all instructors. Active learning score for all instructors except T4 showed an increase. T4 remained at his starting score for Active learning which was high at the start itself (Fig. 4). CuVIS was however, not able to substantially improve the Authentic dimension score for instructors T2 and T3.

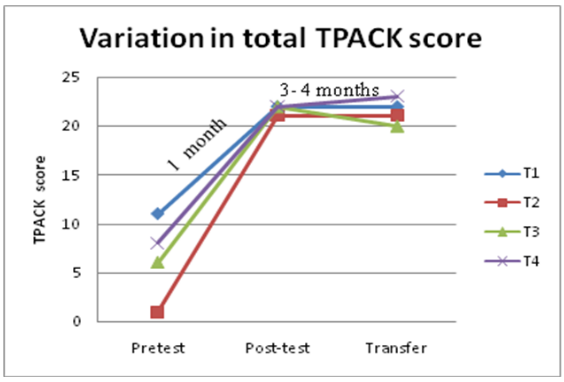

Figure 3. Impact of CuVIS on instructor's total TPACK level

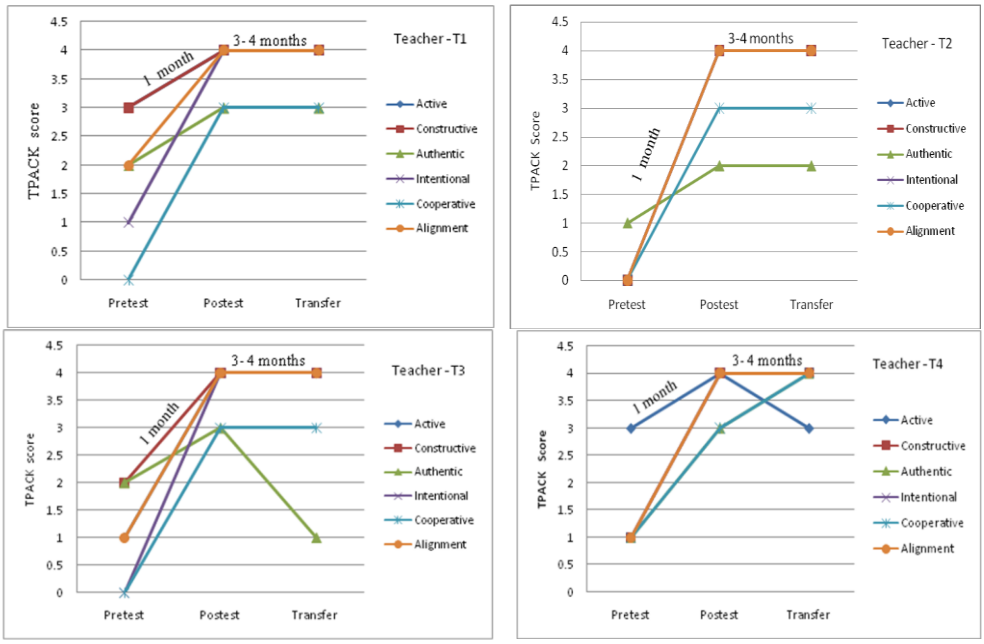

Figure 4. Impact of CuVIS on individual instructor's TPACK levels along each rubric criteria

5.2 Analysis of time allocation and sequence of activities in learning designs

We did time allocation analysis and studied the sequence of activities in each instructor's LDs in order to understand the impact of CuVIS on their pedagogical practice. 3 categories of teaching activities were identified: *Category 1* - Lecturing without student interaction (with or without visualization), *Category 2* - Guided interactive activity with visualization (Individual activity, Group activity, Feedback through visualization) and *Category 3* – Guided interactive activity without visualization.

Category 1 included teaching activities where students were passive recipients of information. Time allocation analysis results showed a sharp reduction in this activity from pretest to transfer phase for all instructors. *Category 2* included student activity with visualization. It included sub-categories of individual and group activities with visualization and feedback activities through visualization (Table 2). This category gave a measure of active student engagement with visualization planned (Kong et. al., 2011). It showed the maximum increase in time allocation among all the categories. The subcategory of group activity with visualization showed the highest increase (mean increase of 28.73% across instructors) (Table 2). Ca*tegory 3* comprising of activities like class-wide discussion not involving the visualization, showed a reduction in time allocation from pre-test to transfer phase.

Table 2: Time-allocation analysis of Category 2: Student engagement with visualization.

Category 2	Sub-category	Instructor	Percentage of time allocated (%)			
			Pre-test	Transfer	Increase	Mean Increase (%)
Guided interactive activity with visualization	Individual activity based on visualization	T1	13.79	24	10.21	15.88
		T2	10	20.4	10.4	
		T3	0	22.86	22.86	
		T4	0	20	20	
	Group activity based on visualization	T1	0	36	36	28.73
		T2	10	38.6	28.6	
		T3	0	30.3	30.3	
		T4	0	20	20	
	Feedback through visualization	T1	3.45	24	20.55	15.45
		T2	0	22.7	22.7	
		T3	20	28.57	8.57	
		T4	0	10	10	

Figure 5 contrasts the sequence of activities in pretest and transfer phases for each instructor. It captures the change in pedagogical practice of the instructors caused by CuVIS along the teaching activity categories identified. All the instructors migrated from lecturing with visualization to doing a series of activities weaved around the visualization. All the instructors reduced, if not completely removed, lecturing with visualization. Instructors T1, T2 and T3 retained lecture activity for a small proportion with the purpose of setting the context for the visualization activity. T4 in fact dropped lecturing with visualization in favor of a guided discovery strategy with static images prior to the visualization activity. This was in sharp contrast to his pre-test LD involving passive lecturing.

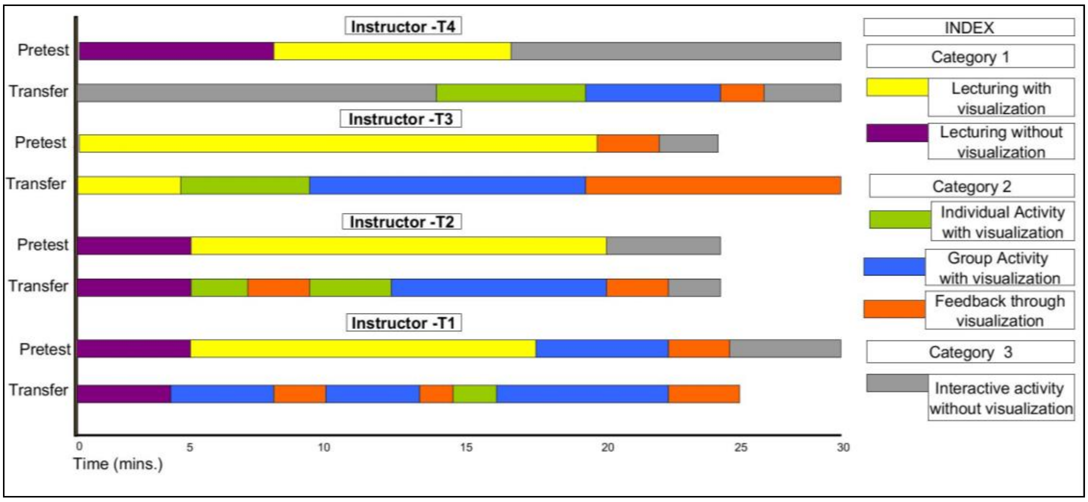

Figure 5. Impact of CuVIS on Sequence of activities with visualization.

5.3 Analysis of instructor interviews

Each sentence in the interview transcripts were taken as the unit of analysis. The similar codes that emerged from the transcripts were grouped into an overarching theme. Thus four themes were obtained – a) Design Problems resolved, b) Scaffolds that helped, c) Benefits of using CuVIS LDs and d) Design Problems unresolved. The theme of 'Design Problems resolved' is defined by the points in the LD creation process that instructors identified as design challenges that instructors could overcome through the use of CuVIS. These include designing constructive alignment, framing active learning questions that exploit visualization affordances and designing field implementation. Instructors were able to overcome these impediments by using the following 'Scaffolds that helped' - LD blueprint with minute level sequencing of teaching activities, domain examples to illustrate guidelines (Fig. 2), self-evaluation checklist with list of common design errors committed by instructors. The 'Benefits of using CuVIS LDs' were identified as facilitating field implementation, increasing student engagement and imparting skills needed by students to make the transition from academics to the professional world. However, instructors listed the following as 'Design Problems unresolved' after use of CuVIS - a) designing activity question anchored in real-life as well as based on visualization (Authentic), b) time overrun during field implementation and c) more time required in planning the class.

6. Discussion & Conclusion

In this section we answer the research questions stated in Section 4.1. We discuss the implications of the results, the limitations of the current study and scope for future research. The first research question targeted impact of CuVIS on instructors' TPACK. The evaluation of the LDs generated by 4 in-service Engineering instructors across the 3 time points was evaluated based on an established rubric. The results showed that all the instructors except T1 were at similar low TPACK levels in the pre-test phase. Only T1 had a high score along the Constructivist dimension in the initial phase itself. A possible reason for this, as identified by T1 herself, was her objective to equip students in learning by doing to smoothen their transition from academics to the workplace. Instructors T2 and T3 reported difficulty with the Authentic dimension. This is a pointer that CuVIS scaffolding for Authentic dimension needs to be strengthened. Overall, CuVIS tool was successful in increasing instructors' TPACK in terms of competency in designing LDs with visualization mapped to Meaningful Learning dimensions and their instructional objective.

The second research question was on impact of CuVIS on the sequence of activities in the LDs from pre-test to transfer phase. 3 categories of teaching activities were identified from the LDs – Lecturing without student interaction, guided interactive activity with visualization and guided interactive activity without visualization. The time-allocation analysis of the LDs revealed maximum increase occurred in guided interactivity with visualization. Within this category, there was a 28.7 % increase in planned group activity based on the visualization. Analysis of sequencing of these activity categories captured the change in instructors' pedagogy from pre-test to transfer. Every teacher brought in Active learning, Constructive, Intentional and Collaborative activities weaved around the visualization and aligned to their objective. In fact, instructor T4 transformed from lecturing to guided discovery with visualization in the classroom. Another positive output of CuVIS noted in the transfer phase was that instructors came up with their own sequencing of activity steps yet retained the learning from CuVIS in terms of Meaningful and effective learning. This proved that CuVIS was able to do the fine balance between being open ended and being a rigid template as recommended in literature (Laurillard et.al, 2013; Bennett et al., 2015).

The third research question seeks to provide answers to some of the pertinent questions in current LD research. Questions on points in the LD process instructors need help in and what type of scaffolding should be provided for this. From analysis of instructor interviews we identified 4 points in the LD process where instructors needed scaffolding. They required support in designing for constructive alignment, framing active learning activity questions based on visualization, implementation design and creating activities with visualization anchored in real-life. CuVIS was able to successfully scaffold instructors in framing activity questions by providing illustrative examples from their domains alongside the theoretical guidelines. CuVIS was able to help in designing the implementation plan by 'micro planning' the steps for the chosen active learning strategy in the LD blueprint. However, CuVIS scaffolding for incorporating the Authentic dimension was partially successful and needs to be strengthened. Thus, the current study contributes to LD research by identifying some of the points where instructors require scaffolding and the scaffolding features that were successful in addressing the difficulty. The tool is useful for instructors to translate the theoretical knowledge of teaching with visualization into practice. Besides, it gives them a tangible theory informed, research based product to implement in the classroom. The tool also serves as a valuable training resource for teacher educators at the tertiary level to cement the learning from training workshops.

The main limitation of the current study was that CuVIS offers limited number of Active learning strategies from the vast array that has proved successful in teaching with visualization for a particular objective. However, CuVIS did not deter instructors in coming up with active learning strategies of their choice in the transfer phase. The current study has been restricted to Engineering instructors and that too to a sample size of 4. We plan to extend the study to larger number of instructors including Science instructors in the future. We also plan to do classroom observation of the implementation of the LDs so designed by the instructors and study the dissonance, if any, between the LD planned and its actual implementation.

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