Effect of instructors' pedagogy and TPACK on integration of computer-based visualizations

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Abstract: Despite the abundance of computer-based visualizations for learning and teaching, instructors are often at a loss as to how to integrate them in their teaching effectively. We present the various ways visualizations are being used by college teachers from science and engineering domains in Indian classrooms. We analyze our findings along five dimensions: Instructional setting and frequency of use, purpose of use, effectiveness as teaching aid, learner engagement level, and pedagogical strategies. We extend our analysis to explore how instructors' *Technological Pedagogical Content Knowledge (TPACK)* affects their use of visualizations along these dimensions. We find that instructors' TPACK has key and significant effects on the pedagogical strategies used to integrate visualizations.

Keywords: Visualizations, teaching aid, learner engagement level, pedagogical strategies

Introduction

Computer-based visualizations such as animations and simulations have proven potential to act as powerful learning resources. They add value to traditional instruction by making the invisible visible [12], promoting higher order learning outcomes through construction of mental models [5], providing learner explorations through multiple representations and fostering more instructor-learner interactions [1]. Their learning effectiveness has been extensively researched upon in empirical studies [9]. While good visualization design [6] is an important factor, the influence of instructors' buy-in and effective integration strategies are also significant. Much of the research on effectiveness has ignored the effects of the instructors' pedagogy [13]. Inclusion of instructors' practices will provide a more complete picture of the effectiveness of visualizations.

1. Impact of instructors on use of visualizations

The instructor's mode of the use of visualizations has significant impact on the way learners use them [2]. Thus instructors need to be equipped with proper instructional strategies to enable learners to derive maximum benefit from these visualizations. Without this, even a well-designed visualization can get reduced to a visual textbook, rather than fostering inquiry-based learning [8]. The assumption that given a good visualization, instructors know its best use is not valid [8, 10]. Integrating computer-based visualization in teaching requires a lot of planning [3]. Successful integration involves not only individual knowledge of domain content, pedagogy and technology, but also the way these parameters interact with each other. Instructors need to be able to choose technologies and appropriate pedagogies that will enhance teaching and learning of a specific topic. Essentially it is the instructors' Technological Pedagogical Content Knowledge (TPACK) [7] which determines the effective integration of visualizations in teaching.

2. Research Question and Context

In the light of findings from literature, our broad research question is: What are various ways in which instructors integrate visualizations in their teaching? We then address the question of how an instructor's TPACK affect their use of computer-based visualizations.
The context of our study is the teaching-learning environment in institutions of tertiary education in India. On the one hand, the Indian government is strongly encouraging the use of ICT in education, by providing funding for various projects to create high-quality ICT-based content for tertiary education [14]. On the other hand, many Indian college classrooms still face a lack of infrastructure to use technology tools in a manner recommended by current education research. Our study is a preliminary effort to identify various factors within this complex setting that play a role in the success of visualizations in teaching and learning. In our setting, students do not have individual access to computers in the classroom. Their interaction with visualizations is mediated by the instructor.

3. Methodology

We conducted this study with a sample of 28 in-service instructors (female =9; male = 19) teaching science and engineering at the tertiary level, from various colleges in western India. The class size varied from 55 to 120 students. Purposive sampling technique employed. A minimum of 2 years of teaching experience was set as a sample characteristic with the assumption that in this time frame, instructors are likely to have considered using visualizations in their teaching. The range of teaching experience was 2 to 32 years with a median of 9.5 years. Most visualizations used by instructors were available in an open-source repository of animations and simulations for college level science and engineering domains (Project OSCAR, [11]).

We followed a mixed methods research design. In the quantitative part of the study, instructors were given the TPACK questionnaire to measure self-perception of their technological, pedagogical and content knowledge. The TPACK instrument has high internal reliability reported (α = 0.78-0.93) [15]. We customized the TPACK survey to our sample base. As part of the qualitative study, structured individual interviews were conducted for 20 minutes each to explore questions such as: Describe the way you use the visualizations. In what instructional settings do you use them? What changes did you make to your normal teaching style? The interviews were recorded and transcribed. The response data were coded using standard content analysis techniques [4] by two raters who showed satisfactory inter-rater reliability.

4. Results

4.1 What are various ways in which instructors integrate visualizations in their teaching?

We answer this research question along 5 dimensions that arose from the interview response codes: instructional settings, purpose of use, pedagogical strategies, effectiveness as teaching aid and learner engagement.

Instructional settings and frequency of use. 61% of instructors (17/28) reported using computer visualizations for up to 40% of their classes. Majority of instructors, 93% (26/28) use visualizations in lectures, while only 36% (10/28) used them in the laboratory setting. 15% (5/28) of instructors assigned homework based on the visualizations.

Purpose of use. Enhancing students' motivation was reported as the main purpose (26/28 instructors, 93%) of using visualizations. Apart from that, instructors' use of visualizations was primarily based on the nature of the domain: for conceptual understanding, to make invisible ideas visible, to understand the nature of 3-dimensinal objects or phenomena. A few instructors reported using visualizations to enhance students' abilities of prediction and their presentation skills (Fig. 1).

Pedagogical Strategies. We group the pedagogical strategies used by instructors into two categories: active and standard. Active strategies are those that are known to promote active learning [13]. Content analysis of our qualitative data yielded the following active pedagogical strategies: Guided inquiry, peer teaching, incorporating higher cognitive level questions during class discussion related to visualizations, accommodating different learner types, connecting to prior knowledge and real-life application, outside classroom support, and providing scaffolding to learners in their zone of proximal development. 14 instructors (50%) used active pedagogical strategies while the other half used standard strategies alone.

Effectiveness as teaching aid: Fig. 2 shows the various roles of visualizations as a teaching aid. Instructors felt that teaching effort was reduced on using visualizations but class preparation time increased. This is consistent with what has been stated in literature.

Learner engagement level: To analyze learner engagement levels with visualizations, we adopted Naps's taxonomy of learner engagement [10]: viewing, responding, changing, constructing and presenting. 71% of instructors (20/28) used visualizations upto responding level while 18% (5/28) used upto viewing level. Among the instructors using active pedagogy, none used visualizations for viewing level alone. 11% (2 instructors) used at higher learner engagement levels of constructing and presenting.

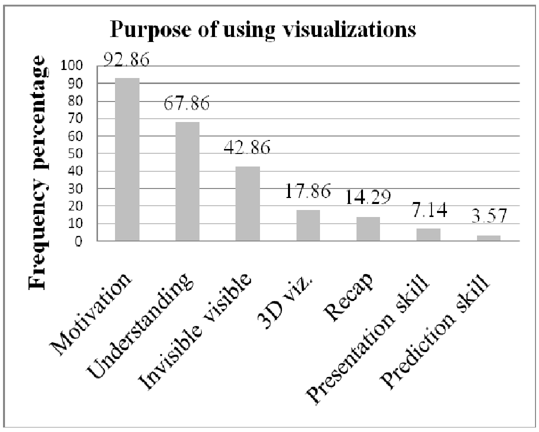

Fig. 1: Purpose of using visualizations

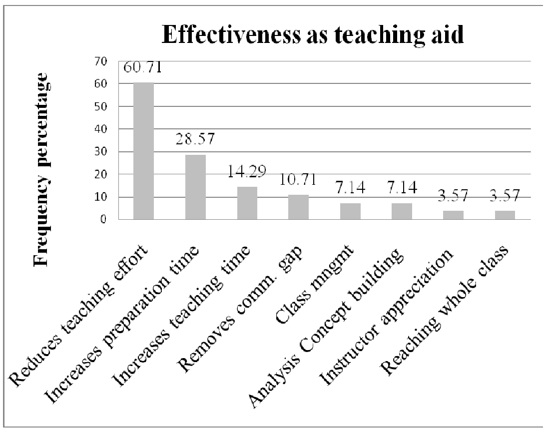

Fig. 2: Effectiveness as teaching aid

4.2 How does instructors' TPCK affect their use of visualizations?

Pedagogical Strategies: We found statistically significant, positive correlation of 0.54 ($p \leq 0.01$) between the total TPACK score of instructors (obtained by summing up the scores across all the constructs in the TPACK survey) and the type of pedagogical strategies used (active or standard). For further analysis, we divided our sample into three groups of high, medium and low TPACK scores. Among the high TPACK group (9 instructors), all implemented active pedagogical strategy while the standard pedagogy approach was seen only in the medium (10 instructors) and low (9 instructors) TPACK groups. Within the high TPACK group, instructors used a wider range of instructional strategies (nine different strategies) than medium and low TPACK instructors (four strategies in each group).

Type of learner engagement promoted: All the 9 high TPACK instructors promoted higher learner engagement levels of responding and constructing. In contrast 6 out of 9 instructors with low TPACK used visualizations upto viewing level only.

Instructional Setting: There was no significant pattern of instructors' TPACK affecting the choice of instructional setting except that only the high TPACK instructors used visualizations for homework assignments and self-study.

Purpose of use: The total TPACK score of instructors did not show any marked variation across the three groups.

There were some discrepancies between instructors' TPACK scores and qualitative data of the pedagogical strategies they implemented in the classroom. In three out of the four such cases, instructors' TPACK score was high, yet they reported never using tools such as computer visualizations. A possible reason for this discrepancy is that the TPACK survey captures only the self-perception of an instructor's confidence in integrating technology.

5. Discussion and conclusion

Instructors in our study used several methods of integrating visualizations that are traditionally cited in literature (for example, to make the invisible visible). In addition, we found that when instructors were hampered by resource constraints and had to use the visualizations merely as a demonstration (viewing level), they introduced their own pedagogical wrap in order to promote higher levels of learner engagement (such as constructing level). Thus, an active learning environment can be built with an 'external lesson strategy' [12]. Majority of instructors (82%) implemented an external lesson strategy either to scaffold learners or to promote higher engagement.

A limitation of our study is that the TPACK survey was meant for pre-service, elementary level teachers who are being trained to use technology tools in their teaching. In comparison, our sample base was in-service college teachers who have not undergone formal training in integrating visualizations. Secondly, a larger sample will allow us to draw more detailed quantitative conclusions between instructors' TPACK scores and other variables. However, the qualitative part of our study has yielded rich data on the ways in which instructors use visualizations.

In conclusion, we have found significant effect of instructors' TPACK on the pedagogical strategies they use to integrate visualizations in their teaching. As part of future work, we plan explore the extent to which different pedagogical strategies promoting active learner engagement makes up for the inadequate student access to laptops in the classroom through classroom observations.

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