Improving Teaching Process Through Technology-Enhanced Instruction for Electrical Machines Course

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Abstract: The use of technology in the classroom has been a regular practice in the 21st century learning as compared to the traditional teaching and learning. However, the technology has been identified as a separate set of knowledge by most of the instructors in their pedagogical practice which is causing problems in effective teaching and learning. This article describes the process of using the conceptual framework of Technological Pedagogical and Content Knowledge (TPACK) which integrates the knowledge of educational with an instructor’s knowledge of pedagogy and course content, to technologically enhance a sophomore-level undergraduate electrical machines course. Concept map tool has been used to integrate and demonstrate the effective utilization of TPACK in the classroom teaching. The effective teaching learning process for the Electrical Machines course has been observed in this paper by designing a course website. The information in the paper will impact the effective integration of technology in teaching and learning process.

Keywords: TPACK, Enduring Outcome, Concept maps, Course Website, Teaching & learning.

1. Introduction
As a teacher in the 21st century, we always try to incorporate educational technology into the classroom to better support students in achieving the intended learning outcomes of the course. However, most instructors view the knowledge of educational technology as a separate entity and fail to integrate effectively technology tools by considering the needs of the students. Education researchers in the K-12 setting believe that the effective integration of the technology tools can be achieved by combining the knowledge of technology with their knowledge of content and pedagogy (Pope et al, 2002). The research studies have shown that instructors need to have a good understanding about how the technology should be integrated with Pedagogy and Content knowledge for effective classroom instruction (Gess-Newsome, 2002). It requires understanding of proper framework to develop the same. This paper introduces the TPACK framework which is an abbreviation for Technological Pedagogical and Content knowledge. The basis of this framework is the understanding that teaching is a highly complex activity that draws on many kinds of knowledge (Mishra, 2006). Renamed TPACK (technological pedagogical content knowledge), the combination of subject knowledge, teaching practices and technological knowledge “form an integrated whole ‘a Total PACKAGE’” (Thompson & Mishra, 2008). Applying TPACK to our classrooms change the way we plan our daily lessons. They describe a planning process where we first choose the learning outcomes that we will be working on that day or during that class session. The learning outcomes are the content. As a second step it is to choose an activity type learning in classroom. The activity type is the pedagogy or how the students are going to learn the content more effectively. Finally, we can choose technologies that will support the activity based learning and aid the students in learning. Knowledge of Content, Pedagogy & Technology form a basic sub domain of an instructor’s knowledge. Knowledge through intersecting of the basic sub domains will lead to Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). Intersecting all the three basic sub domains PCK, TCK & TPK will result in the development of TPACK as shown in the Fig. 1. TPACK is considered as the second-level of transformation developed through a meta-conceptual awareness of the learning needs of the students and the limitations experienced by instructors in traditional mode of instruction. Even after potential
importance of TPACK there has been no consent on the development of the TPACK among researchers and educators. Most of the instructors argue that the TPACK framework is unclear and fuzzy while integrating into the classroom instructions (Graham, 2011) specifically in the complexity of framework, lacking clarity and undefined components. Moreover, a technology enhanced lesson and the TPACK model-for example, the TPACK-based ID model (Lee & Kim, 2014) and the TPACK-COPR model (Jang & Chen, 2010) are frequently used as a strategy to develop TPACK. Teacher education programs should not only be conceptually integrated but also requires authentic experiences. Despite the variety of TPACK models that have been proposed, only a few models consider both teachers' knowledge and teaching experiences (Bell, Maeng, & Binns, 2013). In this context this paper uses concept maps to show the process of technology integration with Content and Pedagogy to plan the course delivery. This concept is specifically designed for Electrical machines course which presents clearly focusing on the enduring outcomes of the course. Technology enabled students learning for the course is also effectively implemented and presented in the paper using course website.

A. Impact on Students

TPACK creates a major impact on the students as the 21st century learners learn and work better with technology and often find the content and teaching quite stale. Hence by integrating the technology content to already existing PCK the students will be more engaged in the learning process.

Research has emphasized the importance of teacher education faculty modelling use of technology in the teacher preparation programs for the development of future teachers’ confidence, attitudes, and adoption of technological innovations in the K–12 classroom (Pope et at, 2002)

B. Impact on Teachers

While there is lot of growth in the technology tools but still majority of the instructors are still falling behind in utilizing the technology tools in the classrooms. The main reason is the instructors lack knowledge about the usage of the technology. Moreover they lack ability to design lectures using technology and teach the classes. Hence TPACK helps the instructors to design and conduct the lectures for their respective courses in the curriculum designed.

C. Concept Maps

Concept map is a graphical or mapping tool for organizing and representing various knowledge domains in a hierarchy. Concept maps were developed in 1972 in the course of Novak’s research program at Cornell where he sought to follow and understand changes in children’s knowledge of science (Novak & Musonda, 1991). Often most of the people confuse rote learning and meaningful learning with teaching approaches that can vary on a continuum from direct presentation of information to autonomous discovery approach where the learner perceives the regularities and constructs own concepts. The direct presentation and discovery teaching methods can both lead to highly rote or highly meaningful learning by the learner, depending on the disposition of the learner and the organization of the instructional materials. There is misconception that “inquiry” studies will assure meaningful learning. The reality is that unless students possess at least a rudimentary conceptual understanding of the phenomenon they are investigating, the activity may lead to little or no gain in their relevant knowledge and may be little more than busy work. This paper implements the TPACK for the Electrical Machines-I course using concept maps. Here the integration of Content Knowledge, Pedagogical Knowledge and Technological knowledge domains are used in the concept maps. Concept maps are also effective in identifying and validating the ideas held by students

2. Methodology

TPACK has been implemented for Electrical Machines course for sophomore-level students in the department of Electrical and Electronics Engineering (EEE). The course consists of DC machines which is one of the core courses for the students of EEE. The course also has a laboratory in the same semester which includes the experiments to be conducted on the topics learnt in the course. The knowledge of the basic TPACK sub-domains i.e. content knowledge, pedagogical knowledge and technological knowledge are mentioned below.

A. Content Knowledge

Phase I is with Content knowledge in which the curricular priorities have been identified as “Enduring Outcomes (EO)”, “Good to know” and “Important to learn”. This paper focuses on the Enduring Outcomes of the course. Enduring Outcomes are the learning outcomes of the topics which should endure (long) after the class is over. Enduring
Outcomes may be difficult concepts, misconception concepts or threshold concepts that need to be mastered before subsequent learning can occur. Few topics from the course were also identified as “Difficult concepts” and “Misconceptions”.

Few of the enduring outcomes are mentioned below:

**EO1**: Apply the faradays law of electromagnetic induction principle to the electrical machines
**EO2**: Identify different parts of a DC machine & understand its operation
**EO3**: Identify the losses in a machine and find its efficiency
**EO4**: Apply the voltage and speed control techniques for a DC machine

The difficulty and misconception concepts were also identified in the course. A sample of each difficulty and misconception is presented here in the Table 1 and Table 2 along with the reasoning of why they are chosen as difficult and misconception from student perspective.

| Table 1. Difficult Concept | Reason |
|-----------------------------|--------|
| Retardation test            | Few of the testing methods on the machines need to find out the friction and windage losses, etc.. They have to calculate the inertia constant also. These were not repeated many times in the core subjects. Hence the knowledge is inert. This is one of the reasons the students find these topics as difficult. |

| Table 2. Misconception Concept | Reason |
|-------------------------------|--------|
| Lenz Law                      | At the beginning of the course the students were confused about the positive and the negative signs for the Emf equation. For example the Lenz law where the negative sign is indicated for response opposing the cause. But the students may be referring few of the text books where the negative sign is not mentioned and they will have the misconceptions on that topic. It can so happen because the students have the habit of mugging the formula rather than going through the explanation part. |

The Concept map is used to indicate the Topics of the course which are mentioned in the Enduring Outcomes linked to the DC machines course. Cmap tool is used to draw the concept map. Red colour object indicates the Course and EO1-EO4 mentioned as small objects represents the Enduring Outcomes. The topics of the course are linked to the EO1 to EO4 using dotted lines as shown in Fig.2. This figure is used to represent the conceptual knowledge using concept map.

**B. Pedagogical Knowledge**

Various pedagogical techniques have been identified to address the above mentioned topics. Cognitive theory of learning has been applied to all the Enduring Outcomes to take the information from working memory to the long-term memory. The cognitive theory of learning has three main parameters which process the mind in learning activities which are “Attention”, “Encoding” and “Retrieval”. (1) **Attention**- whenever new information is observed the learner focuses on the key features to be learned. The working memory holds the information and compares new information with existing information. (2) **Encoding**- New information which is in the working memory is encoded to the long-term memory. (3) **Retrieval**- Long term memory holds all information from past memories in a network of organized associations. All the existing information should be retrieved at frequent intervals to increase the retention ratio. Various pedagogical activities are conducted for the Enduring Outcomes to develop the cognitive theory of learning for the above parameters. A sample Enduring Outcome EO1 from Electrical machines-I course is considered to apply the cognitive theory of learning to address the above parameters attention, encoding and retrieval which is mentioned in the Table 3.

The other Enduring Outcomes are also mapped with the cognitive theory of learning for Electrical Machines course. The other two curricular priorities “Good to know” and
“Important to Learn” can also be mapped. This paper focuses on the enduring outcomes to be mapped. The difficulty and the misconception concepts can also be mapped with the suitable pedagogical activities. Similarly various pedagogical activities are identified for the Content (Topics) in the Electrical Machines Course. To develop the Pedagogical Content Knowledge (PCK), the pedagogical activities are mapped with the Topics (Few topics are mentioned) as shown in the Table 4.

**Table 3. Applying cognitive theory of learning to Enduring Outcome**

| Enduring Outcome | Strategy to get Students Attention | Encoding Strategy | Retrieval Strategy |
|------------------|-----------------------------------|------------------|-------------------|
| EOI              | Explaining its importance by showing applications through Pictures/Videos about how it is applicable for all the machines | Elaborated explanation by showing an animated video of its working principle | Whenever the principle need to be applied to other machine the students were given a chance to retrieve the information by random questioning, demo presentation, etc. |

**Table 4. Content mapping with Pedagogy (PCK)**

| Name of the Topic                  | Pedagogical activity                               |
|------------------------------------|----------------------------------------------------|
| Construction of Generators         | Demonstration in the Laboratory/Classroom by showing parts |
| Flemings Right hand rule           | Displaying Three dimensional Models with examples  |
| Flemings Left hand rule            | Explanation and Think pair share activity          |
| Speed Control Exercises            | Problem solving / Experimental demonstration in laboratory |
| Types of losses in machine         | Concept maps suing tool or charts                   |
| Characteristics of Machines        | Virtual Labs/ simulation                            |
| Working Principle of machines      | Animated Videos in classroom                        |
| Three Point starter               | Animation and Demonstration in laboratory           |
| Solving exercise Problems          | Practice through collaborative and constructive learning |

The other activities can also include Flipped class learning, Quiz, presentations through slides, charts, NPTEL videos, etc.

**C. Technological Knowledge**

The Content knowledge and the Pedagogical Knowledge has been integrated though the mapping in the above sections. In the third phase the Technological knowledge has been mapped/integrated with both the content and pedagogy knowledge (PCK) to obtain the TPACK. Various technology tools have been identified for the course Electrical Machines to understand the concept easier. Animated videos through YouTube, PPTs, NPTEL, Virtual laboratories, Concept maps using technology tools, etc are identified. This paper presents the integration of technology with PCK rather than treating the Technology as a different entity. The Technological knowledge is mapped with the PCK mapped earlier and shown in the Table 4 to form the big picture TPACK shown in the Table 5. Hence a Concept map is taken in this paper to present the integration of three phases Content, Pedagogy and Technology for related topics with effective teaching styles. The technology tool “Cmap” is used to create the concept maps. The concept map is shown in the below Figure the complete TPACK picture. The Colour codes are given for all the three entities Content (Grey), Pedagogy (Green) and Technology (Blue). The concept map shows clear integration of all the three domains and also helps both the instructors and learners to understand the structural knowledge of the course. The instructors can also plan the activities and the technology to be used effectively in the classroom.

A Course website for Electrical Machines is also designed to make the use of technology more effective in the learning process.

**Table 5. Content mapping with Pedagogy**

| Name of the Topic                  | Pedagogical activity                               |
|------------------------------------|----------------------------------------------------|
| Construction of Generators         | Demonstration in the Laboratory/Classroom by showing parts |
| Flemings Right hand rule           | Displaying Three dimensional Models with examples  |
| Flemings Left hand rule            | Explanation and Think pair share activity          |
| Speed Control Exercises            | Problem solving / Experimental demonstration in laboratory |
| Types of losses in machine         | Concept maps suing tool or charts                   |
| Characteristics of Machines        | Virtual Labs/ simulation                            |
| Working Principle of machines      | Animated Videos in classroom                        |
| Three Point starter               | Animation and Demonstration in laboratory           |
| Solving exercise Problems          | Practice through collaborative and constructive learning |
| Name of the Topic                  | Teaching practice (Pedagogy)                                                                 | Usage of Technology tools/methods                     |
|-----------------------------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Construction of Generators        | Demonstration in the Laboratory/Classroom by showing parts                                  | Digital Pictures (Optional)                           |
| Flemings rule                      | Displaying Three dimensional Models with examples                                           | Video self created by faculty or experts              |
| Speed Control Exercises           | Problem solving / Experimental demonstration in laboratory                                    | Simulation Tool / Virtual labs                        |
| Types of losses in machine        | Concept maps using tool or charts                                                            | Concept map can used by Cmap tool                     |
| Characteristics of Machines       | Virtual Labs/ simulation (Flipped Class)                                                     | Course Website can be used for Flipped               |
| Working Principle                 | Animated Videos in classroom                                                                | Videos (Youtube, NPTEL)                              |
| Three Point starter               | Animation and Demonstration in laboratory                                                    | Youtube Video in Class                                |

![Fig. 3 TPACK Concept map](image)

3. Results & Discussion

The big picture of the entire TPACK framework has been developed using concept map which clearly shows the pictorial representation of all the three basic domains integrated together for the Electrical Machines course as shown in the Fig.3. Technology tools like Cmap and Mindmap has been used to draw this concept map. TPACK was used to transform the course using technology and a course website has been developed. Canvas.instructure.com has been used to develop the course website. This website represents a virtual classroom where all the students could be a part of this. The content related to Electrical Machines has been added in the form of PDF, JPEG, PPT, etc. The students were also given discussion and assignments where they can be given a chance to participate in the discussion in group which brings into the pedagogical activities. The instructor can also respond and clarify the doubts in the discussions. This is very useful in implementing the flipped class learning which fulfils the role of integrating technology with content and pedagogy. The students can watch the videos out of the classroom through the website and participate in the discussions in the classroom or also in the course website discussion blog. The screen shots showing the home page of the course website is shown in Fig.4. Activities like online discussion, submission of assignments, watching the videos, accessing materials shows the interest in learning the course using the technology. Creating interest and “attention” towards the learning by discussion questions can also happen which is shown in the Fig.5. The response of the students in terms of the feedback is given outstanding after implementing this methodology is shown in the Table 6.
Table 6. Student Feedback on Teaching methodologies

| Learning | Enthusiasm | Organization | Group Interaction | Individual Rapport | Extensiveness | Examinations | Assignments | Overall | Grading |
|----------|------------|--------------|-------------------|-------------------|--------------|--------------|-------------|---------|---------|
| 4.580246914 | 4.592592593 | 4.525925926 | 4.407407407 | 4.456790123 | 4.469135802 | 4.469136 | 4.537037037 | 4.648148 | A++     |

Grade Points

| Grade          | A++ | A+  | A   | B+  | B   | C+  | C   |
|----------------|-----|-----|-----|-----|-----|-----|-----|
| Grade Points   | 4.51| 4.26| 4.01| 3.76| 3.51| 3.26| 3.01|
| Grade Point Range | >4.51 | ≥ 4.26 &< 4.51 | ≥ 4.01 &< 4.26 | ≥ 3.76 &< 4.01 | ≥ 3.51 &< 3.76 | ≥ 3.26 &< 3.51 | ≥ 3.01 &< 3.26 |

Note: The obtained score is on the scale of 1 to 5 & The faculty Feedback is Outstanding

4. Conclusion

At the end TPACK framework is used to analyse the three major areas Content, Pedagogy and Technology and how they could be integrated effectively into the course context. The strategy should focus more on changing the pedagogical methods, more specifically shifting from a pure behaviourist model and going towards a constructivist approach, where the students can learn with their own pace using methods such as self-discovery, research, experimentation, etc. and can also develop the critical thinking skills and focus towards the enduring outcomes. The concept maps could become a power full tool not only in learning but also as an evaluation tool which encourage students a meaningful mode learning patterns. The course website developed using canvas is an end project of the implementation of TPACK for integrating all the sections and enabling technology enhanced learning. The scope of the research is never ending. This methodology can be implemented to any course and the shape of the concept map and the pedagogy tools vary based on the innovative teaching practices the instructor implements.

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