A Technology-mediated Learning Environment

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Abstract
Implementing a technology-mediated learning environment is a challenge for teachers. They have to not only use the learning materials effectively (pedagogical content knowledge) but also integrate the technology that mediates the learning. It is important that prior to the implementation of technology-mediated learning content in the classroom, teachers feel confident on how to use the technology. Therefore, an effective professional development should be provided to the teachers. This paper includes details of the design and conduct of a professional development workshop on a technology-mediated learning environment for middle school math and science teachers from rural and economically depressed school districts. The teaching of active-learning math and science modules supported by flight simulation software was modelled during a one-week summer professional development. The participating teachers' attitudes were measured using the Math/Science Teaching Efficacy Belief Instruments. The teachers were also administered a post-workshop survey to solicit their perceptions of the effectiveness of the professional development. Analyses of the data indicated high self-efficacy in using the pedagogical approach and confidence in the effectiveness of the pedagogical approach. This paper will share the methodology of developing the pedagogical approach and some results based on the data analysis.

Introduction
The impact of pedagogical content knowledge (PCK) of teachers, a term first coined by Shulman (1987), on student learning has been extensively researched (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007; Smith, 2009; Lange, Kleickmann & Moller, 2012; Park, Jang, Chen & Jung, 2011; Berry, Friedrichsen & Loughran, 2015; Keller, Neumann & Fischer, 2017; Gess-Newsome et al., 2017; Neumann, Kind & Harms, 2019). The advent of low-cost software simulations added a new dimension to the PCK of teachers. Teachers have to prepare their lesson plan (i) leveraging the learning affordances of the simulation environment, (ii) ensuring participation of the students, and (iii) discussing the lessons learned. The effectiveness of simulations on student learning outcomes has been studied in various domains of math and science (Richards, Barowy & Levin, 1992; de Jong, & van Joolingen, 1998; Falvo, 2008; Khan, 2011, Sarabandoa, Cravino & Soares, 2014; Srisawasdi, 2014; Pfefferová, 2015). The simulation environment may not be limited to only software but may also include hardware to bring higher fidelity to the experience. The framework for teacher competencies has thus expanded (Fig. 1) to what has been termed as technological, pedagogical, and content knowledge (TPACK) (Mishra &Koehler 2006). The impact of TPACK of teachers on the student learning outcomes is documented in research literature as well (Farrell & Hamed, 2017).

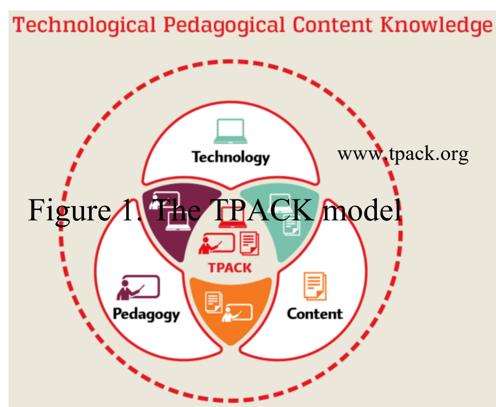


Figure 1. The TPACK model

The need for developing PCK and TPACK of teachers is therefore well recognized. Professional development (PD) of teachers needs to have a deliberate focus on enhancing their PCK (Van Driel & Berry, 2012; Evens, Elen, & Depaepe, 2015). And, if use of technology is involved then the development of the TPACK should be an essential goal of the PD (Lawless & Pellegrino, 2007).

The objective of this paper is to provide details of a one-week long PD summer workshop for middle school teachers of rural school districts. The workshop main objective was to develop the TPACK of teachers using innovative learning with the integration of flight simulation environment (Fig. 2).

Method
During the workshop, the participating teachers were trained in the use of an innovative learning environment for certain math and science concepts using flight simulation software. The week-long PD workshop was designed incorporating the characteristics of an effective PD (Darling-Hammond, Hyler, & Gardner, 2017), i.e.:

a) Content focus,
b) Active learning,

c) Collaboration,
d) Use of models and modeling,
e) Coaching and expert support,
f) Feedback and reflection, and
g) Sustained duration.

The workshop consisted of the following components:
a) Understanding physics of flight,
b) Recognizing and using cockpit instruments and controls,
c) Flying a mission designed for the specific math or science concept
d) Collecting and analyzing flight data to learn the concept.

The teaching of a math and science lesson using the flight simulation software was modeled by the workshop facilitators. The teachers then were given the opportunity to collaborate in pairs from math and science to develop their own lessons incorporating the flight simulator hands-on activity. Each pair of teachers presented the lesson followed by discussions (Fig. 3).

Figure 2: Large Screen Flight Simulator

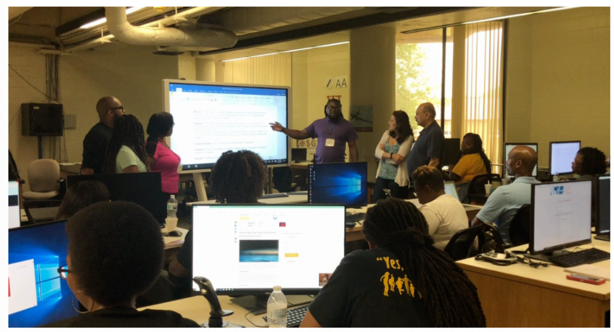


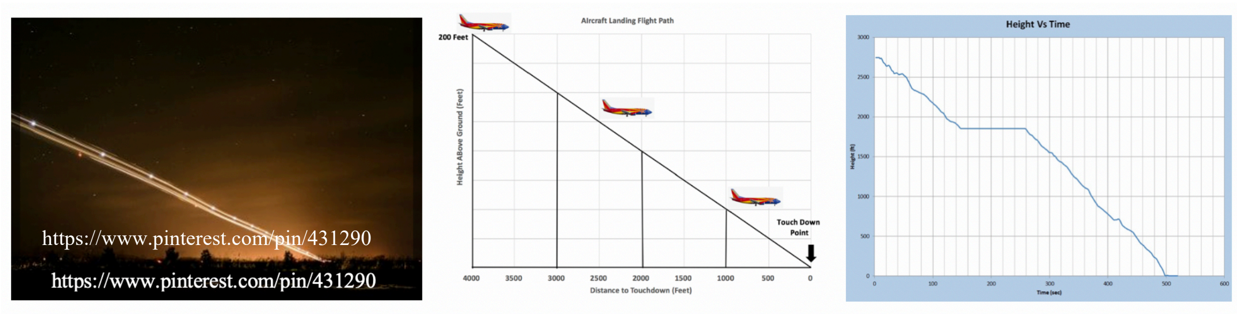
Figure 3: Teachers presenting their lesson

Participants
The workshop participants (N = 23, male = 8, female = 15) were middle school teachers from economically depressed rural school districts. A total of 12 math teachers and 11 science teachers participated in the workshop.

Materials
The participants were provided PowerPoint presentations on (i) the physics of flight, (ii) cockpit instruments and controls, (iii) collection of flight data, and (iv) analysis using Excel.
The lessons that were modeled during the workshop were based on math and science concepts identified in consultation with the local school district teachers. The website www.flyhightu.weebly.com provides details of all the learning materials that have been developed under the project.

The math and science topics which were delivered as models were "Similar Triangles and Pythagorean Theorem" and "The Atmosphere". These lessons, designed on the 5E principle (Engage, Explore, Explain, Extend, Evaluate), consisted of the following components:
(a) Basic concepts of the math and science topics (for example for the science lesson, the various layers of the atmosphere were explained)
(b) Paper and pencil activities for each lesson
(c) Appropriately designed hands-on activities using the flight simulation software to collect data (i.e. a landing flight for similar triangles lesson, and a climbing flight for the atmosphere lesson)
(d) Analysis and interpretation of the collected data
(e) Assessment of concepts

The flight simulator hands-on scenario for the math module "Similar Triangles and Pythagorean Theorem" consisted of landing an aircraft using a straight-in approach. Typical landing patterns (Fig. 4a) were shared as an introduction. The teachers made the comparison between the real-life landing pattern with the paper pencil activity (Fig. 4b). Thus, a connection between a real-world problem (such as the allowable location of a building with a specific height) and the use of similar triangles can be explained for a deeper learning of the concept. This discussion was followed by flying the simulated landing approach to collect data and analyze it using Excel (Fig. 4c). The same scenario and data were used to determine the unknown height or distance from the touch down point using the Pythagorean theorem.

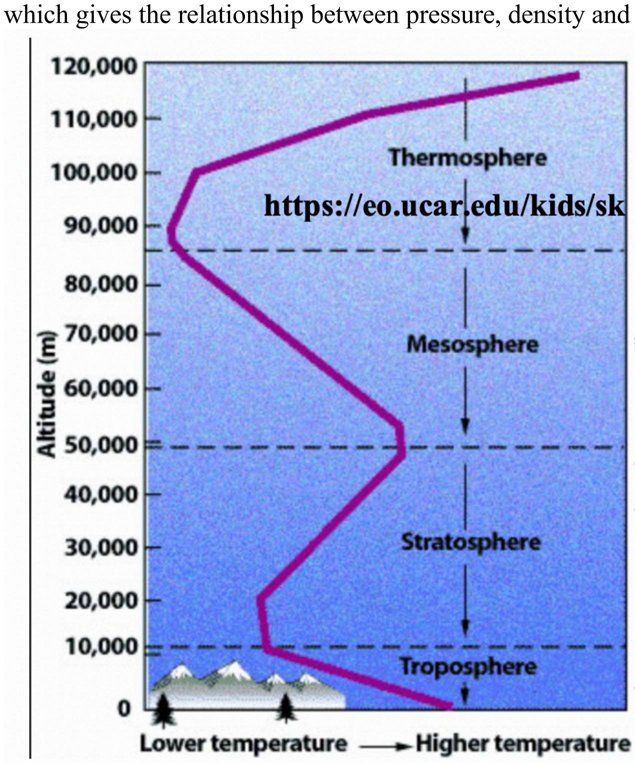


(a) Night landings (long exposure) (b) Paper-pencil activity (c) Flight simulator data

Figure 4. Similar triangles lesson

Teachers were asked to come up with problems on similar triangles and/or the Pythagorean theorem using the collected data from the landing scenario. These problems can be then incorporated in their teaching to strengthen the understanding of these concepts and demonstrate the connection to real life.

The layers of the standard atmosphere (Fig 5a) were first discussed with the teachers. This discussion was followed by the teachers flying a climbing flight scenario to collect atmospheric data on temperature with altitude (Fig. 5b). It was noted that the maximum height to fly was in the Tropopause layer. The data was then analyzed on Excel by the teachers to calculate other quantities such as atmospheric pressure and density using the standard atmospheric model which gives the relationship between pressure, density and temperature.



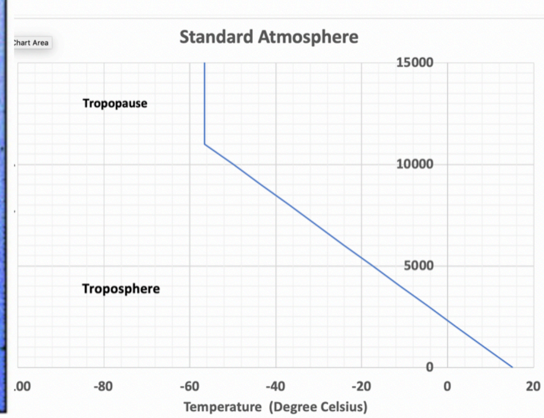


Figure 5a. The standard atmospheric model Figure 5b. Flight simulator data

The effect of a non-standard atmosphere on the Troposphere and Tropopause layers was then demonstrated by changing the “lapse rate” i.e. rate of reduction of temperature with altitude or the sea level pressure and temperature.

The teachers pre-post workshop attitudes were measured using the 25-item Science/Math Teaching Efficacy Belief Instruments (S/MTEBI), (Riggs &Enoch, 1990; Enochs, Smith & Huinker, 2000) using a 5-point Likert scale. These instruments measure the Teaching Efficacy Belief (TEB) with 13 items, and Teaching Outcome Expectancy (TOE) with 12 items. An additional 5-item measured the attitude towards implementation of technology in teaching (ITT). The teachers’ perceptions of the effectiveness of the PD and the pedagogical approach were also measured using a post-workshop questionnaire.

Results and Discussion

The pre-post data from the S/MTEBI was analyzed. An increase in the mean of the three dimensions was observed from pre-workshop to post-workshop Table I; however, the increase was not statistically significant ($p < 0.05$)**.**

Table I: Pre-post Means of TEB, TOE and ITT

	Science + Math Teachers		Science Teachers		Math Teachers	
Dimension	Pre	Post	Pre	Post	Pre	Post
TEB	4.28	4.37	4.33	4.46	4.24	4.28
TOE	3.54	3.65	3.3	3.48	3.76	3.81
ITT	3.99	4.10	3.96	4.06	4.02	4.13

The mean responses to several questions within each dimension registered a statistically significant ($p < 0.05$) increase from pre-workshop to post-workshop (Table II).

Table II: Pre-Post Mean Responses to S/MTEBI Questions (* $p < 0.05$)

	Science and Math Teachers		Science Teachers		Math Teachers	
Dimension/Item	Pre	Post	Pre	Post	Pre	Post
TEB						
I am not very effective in monitoring science/math activities. (reverse scored)	3.83	4.17	3.91	4.55*	3.75	3.83
I do not know what to do to make students interested and like science/math. (reverse scored)	3.91	4.17	4.18	4.55*	3.67	3.83
TOE						
Even teachers have good science/math teaching abilities they cannot help some students (reversed scored)	2.78	3.43*	2.00	3.45*	3.50	3.52
The inadequacy of a student’s science/math background can be overcome by good teaching.	3.96	4.17*	3.91	4.27*	4.00	4.08
Even teachers have good science/math teaching abilities, they cannot help some students to learn science/math. (reverse scored)	2.78	3.43*	2.00	3.45*	3.05	3.42
Students' achievement in science/math is directly related to their teacher's effectiveness in science/math teaching	3.57	3.78	3.18	3.55*	3.92	4.00
The low science/math achievement of some students cannot generally be blamed on their teachers (reverse scored)	2.78	3.05	2.36	3.00*	3.17	3.08

The participants of the workshop were also given a 30-item post-workshop survey to determine their perceptions of the pedagogical approach and the effectiveness of the professional development. The following questions from the survey were used to solicit opinion of the workshop participants regarding the pedagogical approach:

(a) The flight simulation environment is useful for teaching the connection between science and mathematics.

(b) I intend to use some if not all of the modules in my classroom.

The responses to the above questions shown in Figs. 6a, b indicate that 91% of the participants strongly agreed or agreed with the use of the flight simulation to teach some math and science topics. These results show that the teachers became confident to integrate technology in their classrooms.

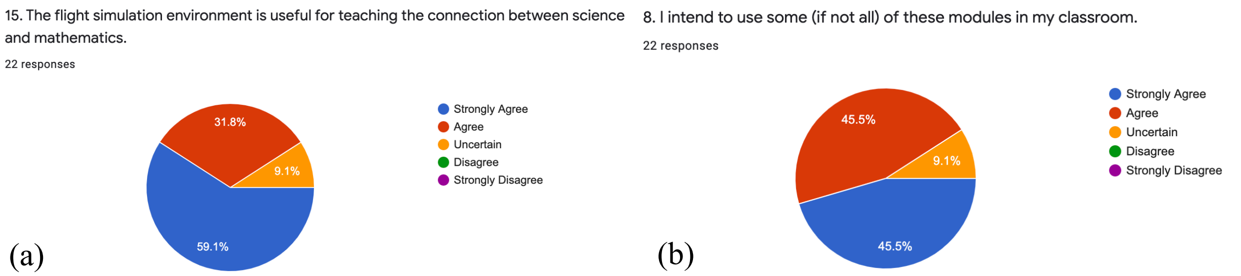


Figure 6. Pedagogical Effectiveness

The design of the professional development and its effectiveness was measured by the following survey items:
(a) The instructors were effective teachers
(b) Adequate time was allocated to the hands-on activity for developing a lesson
(c) The workshop has provided adequate knowledge and training to use the flight simulation environment in the class room
(d) Overall, this workshop was a successful professional development experience for me.

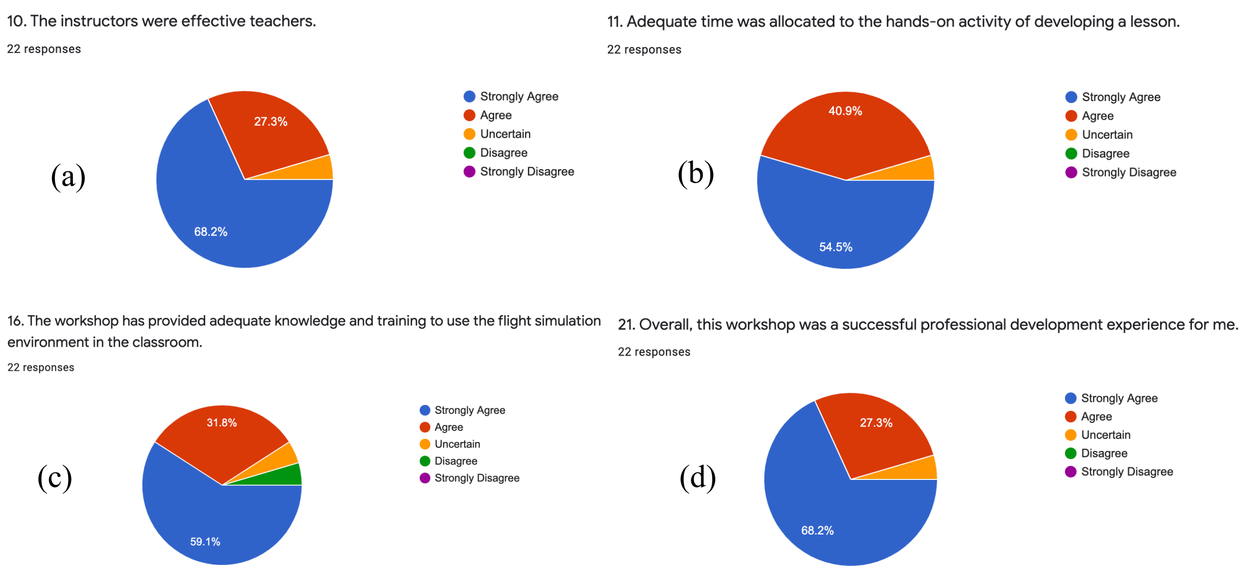


Figure 7. Professional development effectiveness

Based on the above results, 95%, 94%, 90%, and 95% of the participants strongly agreed or agreed with the four items respectively, showing the positive impact of the workshop. These results confirm that the professional development was designed according to the best practices as cited above (Darling-Hammond, Hyler, & Gardner, 2017).

Conclusion

The professional development resulted in increasing the confidence of teachers to integrate technology in the classroom. The teachers considered the pedagogical approach to be useful in demonstrating connections between math and science concepts to their students. The collaboration of teachers from different subjects and different schools to develop and present their lessons created an opportunity for networking. The approach was successfully implemented in a one-week long summer camp for middle school students. Two of the workshop participant teachers assisted the authors in the conduct of the camp. The results of the summer camp are reported elsewhere.

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