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A Content, Pedagogy and Technology [CPT] Approach to TPACK

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Abstract: *TPACK is a framework for the learning process in which educators combine Technological, Pedagogical and Content Knowledge to deliver the learning experience. Therefore, TPACK can be defined as a complex interaction between the technology, pedagogy and content. TPACK expresses the overlap between these factors in a two-dimensional space, placing TPACK at the centre.*
Educators can place their teaching episode within this space and ask, if I place my delivery at this point is it the best point in the TPACK space? Secondly educators may ask how can the best point within the space be determined?
The CPT model proposes an attempt to address these questions by recasting TPACK as a three-dimensional pseudo-vector space allowing expected outcomes and observed outcomes to be analysed.
For the study presented here our null hypothesis is:
H_0 = there is no significant difference between the observed and expected outcomes.

1. Introduction

The TPACK is generally credited to Shulman (1986, 1987) where he described it as PCK (The Pedagogical and the Content knowledge) and its interaction with the technology in order to bring about effective teaching. What is now known as TPACK is generally credited to the work of Mishra and Koehler [4, 8].

As shown in figure 1 the TPACK consist of three components content knowledge, pedagogical knowledge and technological knowledge, migrating these components and elements will produce common areas where you can find two or more elements interacting with each other. These areas represented as PCK (pedagogical and content knowledge), TCK (technological and content knowledge), TPK (technological pedagogical knowledge), and TPACK, which is considered as a result for the interaction between PCK, TCK and TPK.

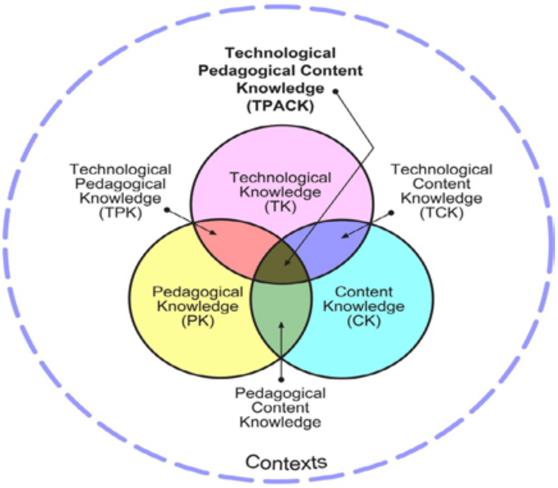

Figure 1. The TPACK framework and its Knowledge Components (M. Koehler & Mishra, [9])

The use of technology in the learning process inside the classroom will bring a new group of variables to the teaching context, and adds complexity due to its rapidly changing nature (Koehler & Mishra, [4]). The TPACK framework identifies a unifying structure that not only respects this complexity, but also provides guidance for appropriate technology integration (Koehler & Mishra [4, 8]). The TPACK framework describes the knowledge, which is required for the teachers to teach effectively using technology, and the complex ways in which these bodies of knowledge interact with one another.

Archambault & Barnett [1] go, as far as to state, "TPACK is potentially useful, especially when conceptualising how the affordances of technology might be leveraged to improve teaching and learning"

The TPACK model is built on the approach presented by Shulman (1986) of pedagogical content knowledge (PCK), in this approach Shulman described the teacher's knowledge of pedagogy and the teacher's knowledge about the taught subject (the content knowledge). Shulman argued these two variables cannot be described individually in isolation but rather teachers need to use the interaction between pedagogy and content to help the learners and to lead them to deep understanding for content they are studying. The TPACK framework extends the Shulman's idea (1986) of PCK by including one more variable - Technological knowledge (TK).

1.1. Content Knowledge

Content knowledge (CK) can be defined as the teachers' knowledge of the subject they teach. CK is a very important factor for the teacher, according to Shulman (1986), the content knowledge includes the knowledge about the concepts, theories, ideas, organisational frameworks, knowledge of evidence and proof, as well as established practices and approaches toward developing such knowledge. This knowledge differs greatly from one field to another. If we consider science, for example, then the teacher needs to have a deep understanding of the fundamental concepts related to the topic they are teaching including the scientific facts, theories, the scientific method, and evidence-based reasoning. If we consider the humanities based subject then the teacher may need to have a historical understanding of the subject, deep understanding and analysis which is theory based. The cost of not having a comprehensive base of content knowledge can be prohibitive; for example, students can receive incorrect information and develop misconceptions about the content area [11, 12]. However, it must also be stated that the depth of understanding required of a teacher in terms of content is, of course, dependent on the level of education of the learners

1.2. Pedagogical Knowledge

Pedagogical knowledge (PK) is the teachers' methods and skills in teaching which should be in continuous development or the methods that are used by the teachers to implement the learning process (the methods of teaching and learning), to manage the class, to organise the lesson time and to help the learners develop a deeper understanding of the content they are studying. The PK, needs experience of the models and theories that are related to the learning process and how these models and theories could be applied to learners in the classroom.

Pedagogy as an expression can be defined in many ways, in this study it will be defined as the combination of the knowledge; skills and the available facilities for the effective delivery of a successful learning experience. Or as Lovat writes it "a highly complex blend of theoretical understanding and practical skill" [7].

As long as the term effective pedagogy has been mentioned as an essential element to lead to a successful learning process then the term effective teachers should also be mentioned, the effective teachers "have a rich understanding of the subjects they teach and appreciate how knowledge in their subject is created, organized, linked to other disciplines and applied to real-world settings. While faithfully representing the collective wisdom of our culture and upholding the value of disciplinary knowledge, they also develop the critical and analytical capacities of their students" [10].

1.3. Pedagogical Content knowledge

PCK is the combination of pedagogy and content knowledge, the teacher combines what is to be taught (the content knowledge) and how it is to be taught (the pedagogical knowledge) to form the PCK which was the core idea for Shulman in 1986, based on Shulman's view, the teacher's knowledge should include two dimensions the first one is the curriculum [i.e. the content that is to be delivered] knowledge, the second one is the knowledge and the back ground of educational theories.

According to Shulman, PCK is a form of practical knowledge that is used by the educators to guide their actions in highly contextualised classroom settings. This form of practical knowledge consists of:

1. To be able to structure and to introduce the content of the lesson for direct teaching to students.
2. The teacher must have a sufficient experience about the difficulties and the misconceptions that students encounter in their learning.
3. The teacher must have a sufficient experience – knowledge about the teaching methods and strategies, In the view of Shulman (and others), pedagogical content knowledge builds on other forms of professional knowledge, and is therefore a critical—and perhaps even the paramount—constitutive element in the knowledge base of teaching [13].

1.4. Technological Knowledge

The problem of defining technology that any such definition rapidly becomes outdated due to the continuous development and availability of the technology itself. Technological knowledge TK exists in a state of flux, due to the rapid rate of change in technology [9]. In general the technological knowledge includes the ability to deal with, for example, the software and hardware and in addition the ability to adapt the new technologies to be used for the benefit of the learning process, the definition for the technology knowledge had been suggested by the Committee of Information Technology Literacy of the National Research Council [11], according to this committee the Technology Knowledge (TK) or the Fluency of Information Technology (FITness) should go beyond the basic level, according to FITness , to achieve the goals using the technology (in other words for effectively use of technology), the understanding of the technology should be deeper, the person must have a deep understanding , sophisticated skills in the Technology Knowledge (TK) and the ability to be adaptive with the new technology, the view of the National Research Council [11] will allow the people to achieve many tasks in at the same time and in an accurate manner, and in a way will lead the generations for a strong Technology Knowledge (TK) background had been constructed over many generations.

1.5. Technological Content Knowledge

Technological content knowledge (TCK) is the common area between Technology and content knowledge. More simply, this field is about how the technology can be used and integrated within the content of the subjects, which can lead to new methods of teaching which will hopefully improve the learning process. For example, the digital simulations may help the students to realise and to conceptualize a complex concept within science in general the new technologies have offered the learners a new understanding and imagining for the world. The Technological Content Knowledge (TCK) relies on the teacher who is the master for these tools and is the one who must match the suitable technology with the content by choosing the best suited technologies for addressing the subjects. In other words, the teacher is the one who dictates the technology for the content and at the same time the content for the technology. For example, the students these days can study the geometric shapes and the angles using the portable devices like the iPad “touching and playing, game based learning. … etc.), therefore the new technologies simplified such difficult and complex concepts for some students. Furthermore, the new technologies enable the learners to have an opportunity for discovering new content.

1.6. Technological Pedagogical Knowledge

The Technological Pedagogical Knowledge (TPK) makes it easy to realise the role of technology in achieving the target of the pedagogic dimensions, based on this, the teachers will have to choose the most appropriate technology for the specific pedagogical approach. Furthermore, the technology can offer the teacher new teaching methods will help to improve the learning outcomes.

TPK this area is the common area between the Technology and the Pedagogical Knowledge or in other words, this area is gathering between how we teach, using which method and what do we use to implement our teaching. Undoubtedly the learning or the education in general will be changed when you insert to it the new technologies to be used in a specific way leads to adapt the education shape and keeping the essential, to be closer to the generation’s needs. For example, the social media sites (technology) are helping the people in making a social learning (pedagogy dimension) by making groups across the world to share and exchange their experience. The significance of TPK due to the fact that the software programs (Microsoft office, the Messenger MSN and yahoo, etc.) were not invented or directed towards the education specially the stage of the school (grade 1 to grade 12) but was created and directed towards business mainly, which left a gap between education and technology was filled by the TPK. The iPad or any other android tablet can be considered as a good example of the TPK, these sorts of devices offers the technology in many shapes (Apps) some of it is useful for the social learning, others are valid for the collaborative learning, others for the direct learning and finally the competitive learning.

1.7. Technological, Pedagogical and Content Knowledge

TPACK is the combination, which is produced due to the interaction between the three main components (technology, pedagogy and content knowledge), TPACK is the framework for the effective education using the technology with a sufficient experience in the constructive methods of teaching.

TPACK can be redefined as; the pedagogical dimensions that use the new technologies in constructive methods to deliver subject content in a manner that offers the learners a new understanding of the world around them.

Basically the combination of these three factors technology, pedagogy and content knowledge have formed and shaped the TPACK model to be considered as the most important element in the learning process, the TPACK in the learning process can lead to success or failure process or outcomes, it depends on both the student and the teacher, everyone has his own role for it to be successful, the students have to improve their skills in the ICT as a receiver, their social communications and his critical thinking to be able to deal with the pedagogy dimension can be used inside the classroom, and regarding the teacher has to develop his skills in the ICT as well but as a sender, has to have a deep understanding for the pedagogy dimensions and to have a strong back ground about the taught subject therefore TPACK does not mean that the teacher has to deal with each element of (T, P, and C) separately but it means in simple words that the teacher has to create the pot where he needs to place these elements together for the complex interaction amongst them to take place which can be considered later as the integration between the technology and the education.

Separating the three components (content, pedagogy, and technology) is an analytic act and one that is difficult to tease out in practice. In actuality, these components exist in a state of dynamic equilibrium or, as the philosopher Kuhn [5] said, in a state of ‘‘essential tension’’…. Viewing any of these components in isolation from the others represents a real disservice to good teaching. Teaching and learning with technology exists in a dynamic transactional relationship (Bruce, [2]; Dewey & Bentley, [3]) between the three components in our framework; a change in any one of the factors has to be ‘‘compensated’’ by changes in the other two [8].

The three factors in TPACK (content, pedagogy, and technology) complement each other, the technology and the pedagogy must be used as a supplement for the content knowledge not instead of it, to facilitate the subject content delivery to the learners and to give a variety in the delivery methods.

2. The CPT model

The CPT model reorganises TPACK area by dividing this area into a three dimensional pseudo-vector space. The significance of the CPT model is to find the likely progress (the expected progress) in the students' level due to the use of technology, in other words to point out (to map) the position of the learning process and the student's progress.

Three factors were investigated in this model, C, P and T (C is Curriculum or Content, P is Pedagogy and T is Technology) which led to modelling via the concept of the vector space which is defined in physics and mathematics using three vectors X, Y and Z as shown in figures 2 and 3. In this study the vector space will be defined using three different vectors (C, P and T) as of X, Y and Z-axes. The magnitude, of the 'progress' vector (r) is then given by:

$$r = \sqrt{C^2 + P^2 + T^2}$$

If no technology is used in the delivery, then this reduces to:

$$r = \sqrt{C^2 + P^2}$$

Hence the enhancement from the technology can be defined as:

$$r_{enhanced} = \sqrt{C^2 + P^2 + T^2} - \sqrt{C^2 + P^2}$$

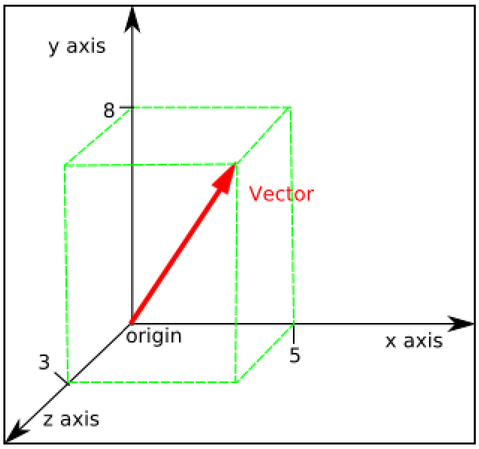

Figure 2: three dimensional vector, the head of the vector can be defined by the point (x,y,z which is represented by 5,3,8 in this figure as an example only), the point x,y, z will be replaced in this study by the vector r (the expected progress) to be represented as C,P,T

The CPT model was applied with a sample of 124 students their assessments results were used to check the validity of the CPT model, these data have been analysed provisionally. *Using the CPT model, the* students' progress could be *predicted* using a three-dimensional vector space (Figure 2 and 3) to develop a data capture tool in the form of 3D equations (equations 1, 2 and 3). After the integration between the ICT and the learning, the students' observed and predicted progress (that was calculated using the equation shown below) was compared. The rates of the observed and the predicted progress were very close to each other, which can be considered as an indicator that this equation can be used for the purpose of calculating the students' level and performance.

The predicted progress (Rn) =
$\sqrt{Cn^2 + Pn^2 + Tn^2}$ - $\sqrt{Cn^2 + Pn^2}$ ……...1

Or
The predicted progress (R_n) = $R_{.}(n)^2$ ……. 2

Simply you can find the value of **R.** Using the following formula

R. = $\sqrt{Cn^2 + Pn^2 + 0.2^2}$ - $\sqrt{Cn^2 + Pn^2}$ …3

Knowing that (n) can take values from 1 to 5. And T1=0.2, T2 = 0.4, T3 = 0.6, T4=0.8, T5=1

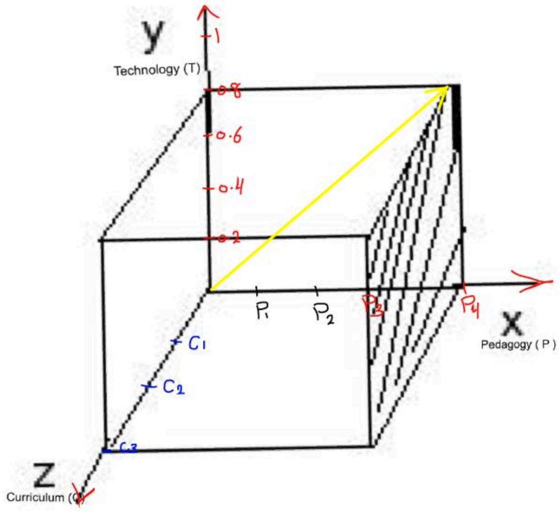

Figure 3. Assessing the student's progress using a three dimensional space CPT

Curriculum
C 1 → purely theoretical;
C 2 → theoretical + practical
C 3 → theoretical + practical + interactive

Pedagogical approach:
This axis draws on the work of Lin (Lin et al, 2012) who argue the case for four dimensions of pedagogy, direct teaching, cognitively active learning, constructive learning and social learning, in this paper the pedagogy dimensions will be distributed as follows:
P1 → the teacher applied only one dimension of the pedagogies in the learning process.
P2 → the teacher applied two dimensions of the pedagogies in the learning process.
P3 →the teacher applied three dimensions of the pedagogies in the learning process.
P4 →the teacher applied four dimensions of the pedagogies in the learning process.

Technology integration:
T1 → 20% of teaching using ICT.
T2 → 40% of teaching using ICT.
T3 → 60% of teaching using ICT.
T4 → 80% of teaching using ICT.
T5 → 100% of teaching using ICT.

2.1. CPT Model – Expected results

Example: C1, P1, T1 = (1, 1, 0.2)

The predicted progress (Rn) =
$= \sqrt{C1^2 + P1^2 + T1^2} \,.\, \sqrt{C1^2 + P1^2}$

The predicted progress (Rn) =
$(Rn) = \sqrt{1^2 + 1^2 + 0.2^2} - \sqrt{1^2 + 1^2}$

The predicted progress (Rn) = 0.014
Which can be calculated using the following formula:

The predicted progress (R_n) = R. (n) ^{2}
From equation 2:
$R. = \sqrt{1^2 + 1^2 + 0.2^2} - \sqrt{1^2 + 1^2}$
R. = 0.014
n: the integration rank. From 1,2,3,4, 5
In this case n= 1
R1= 0.014 x $(1)^2$ = 0.014
which is the same value at point (1, 0.2, 1).
And so on for the rest of the points.

Using the previous steps, I run the CPT model - Cn, Tn, Pn with different values of **n** and the results of the predicted progress is shown in the below (Table 1).

Table 1. The CPT model - Cn, Tn, Pn with different values for n and the results

Cn, Tn, Pn	The predicted progress rate (Rn) = $\sqrt{Cn^2 + Pn^2 + Tn^2}$ - $\sqrt{Cn^2 + Pn^2}$	The predicted progress (R_n) = R. (n) ^{2}
C1, T1, P1	0.014	0.014
C1, T2, P1	0.056	0.056
C1, T3, P1	0.123	0.126
C1, T4, P1	0.211	0.220
C2, T1, P2	0.007	0.007
C2, T2, P2	0.028	0.028
C2, T4, P2	0.111	0.110
C3, T1, P3	0.005	0.005
C3, T3, P3	0.042	0.042
C3, T4, P3	0.075	0.075

Note: Table 1 is not exhaustive (not all possible cases are shown).

3. The Study

This study was used to test the CPT model and to check the validity of the equations of this model. This stage focused on the students in order to measure their enhanced progress due to the use of ICT in education. Students were assessed many times and the collected results were analysed in this stage.
This study focused on the analysis of the effect of using technology on the student's performance as predicted using the CPT Model's formulas.

3.1. Methodologies

In this study I used comparative methodology. The students' observed and predicted progress (that was calculated using the equations in the CPT model) was compared by the researcher.

Three instruments were used to collect primary data: a pre-study survey, student reflections for class projects and a post-study survey. All participants were required to complete the pre-study survey, which was administered one week prior to the beginning of the study mainly to establish baseline performance data across each subject. This study focused on the effect of using technology on the student's performance; study the students' attitudes and perceptions towards the effectiveness of mobile learning; and how students perceive the use of mobile devices to create a personalized learning experience outside the classroom. After completing each class project, students were required to complete a student reflection as a separate assignment. The post-study survey scores were used as a proxy for understanding how exposure to and use of mobile technologies by students can impact their overall attitudes to adopt new learning strategies.

A specialized learning environment (technological facilities – iPads, laptops, learning management system; variety of pedagogy dimensions; positive and clean environment) was created to simplify the students' use of their mobile devices, when tasked to complete the different mobile activity assignments or to do a test. Students could post their responses to topic prompts that the instructor had posted on a discussion board and then respond to postings made by their peers. This learning site "Plato" (the learning management system which we use in our institution) facilitated the use of social online.

Class assessments were designed according to the following criteria:

(a) Assessment must require the use of mobile devices.

(b) Assessment must demonstrate the use of everyday technologies.

(c) Assessment must demonstrate both quantitative and reflective information that it promotes new learning experience with mobile technologies.

3.2. Participants in the study- students

One hundred twenty-four students participated in this study from six different classes within the same grade. School authorities' permission was received to use students' works and marks in this research. The participants' average age was 17. All participants completed five class projects designed to help them explore mobile learning experiences with their own mobile devices. All students were enrolled in more than one class in which they used the mobile devices.

3.3. Data analysis and discussion- the CPT model – Expected and Observed results

Case # 1

Thirty-five students were included in this study. I applied the (C3, T3, P3) method: it means that Curriculum had all three parts theoretical, practical and interactive; I managed to integrate the Technology with 60% of the subject (lesson); and had applied three Pedagogical dimensions. Then I made a test to evaluate the students - 60 % of it to be done online and 40 % using the traditional facilities. I collected the results to analyse using MS Excel.

In this case the Expected improvement (calculated from the formula) = 0.0422 and the observed improvement (AVG = 0.052857143). The two values are very close to each other; this could be considered as an index for the strength of the equation. The Chi square value "0.987" is less than the critical value 3.841 which means the null hypothesis cannot be rejected, it should be accepted, in other words NO significant difference between the expected values and the observed values. Please refer to the data in table 2 (a and b). The analyzed results were compatible with my equation as shown below

Mathematically:

Regarding Case # 1 the point should be (3, 0.6, 3):

$$\textbf{The predicted progress (Rn)} = \sqrt{C3^2 + P3^2 + T3^2} - \sqrt{C3^2 + P3^2}$$

$$\textbf{The predicted progress (Rn)} = \sqrt{3^2 + 0.6^2 + 3^2} - \sqrt{3^2 + 3^2}$$

$$= \mathbf{0.0422}$$

The same result can be found using equations 2 and 3 as shown below:

$$\textbf{The predicted progress } (\mathbf{R_n}) = \mathbf{R_.(n)^2}$$

R. = 0.004711
If n= 3
Then
$R3 = 0.004711 \times (3)^2$
= 0.042 which is the same value that I get above at point (3, 0.6, 3) or (C3, T3, P3).

For the cases 2, 3 and 4 please see Table 2-a

Table 2-a: the CPT model – Expected and Observed results – cases from 1 to 4

Case #	# of students	Cn, Tn, Pn	Percentage of technology (%T)	Content of the curriculum	Pedagogy dimension
1	35	C3, T3, P3	60%	Theoretical + practical + interactive	Direct, constructive and social learning
2	35	C3, T4, P3	80%	Theoretical + practical + interactive	Direct, constructive and social learning
3	28	C2, T4, P2	80%	Theoretical + practical +	Direct and social learning
4	26	C1, T1, P1	20%	Theoretical +	Direct learning

Table 2-b. Summary of observed improvement against the expected improvement in different cases of CPT Model.

Case #	$C_nP_nT_n$	The AVG observed progress	The predicted (expected) progress $(Rn) = \sqrt{Cn^2+Pn^2+Tn^2} \cdot \sqrt{Cn^2+Pn^2}$	P_{value}	$\Sigma\chi^2$	The final result based on $\Sigma\chi^2$ and the P_{value}
1	C3, T3, P3	0.053	0.042	< 0.05	0.99	*NO significant difference between the expected values and the observed values.*
2	C3, T4, P3	0.080	0.075	< 0.05	1.94	
3	C2, T4, P2	0.107	0.111	< 0.05	2.70	
4	C1, T1, P1	0.020	0.014	< 0.05	1.17	

Table 3 and Figures 4 and 5 show the observed improvement against the expected improvement in different bands {band 3 (B3): "C3, P3, T3" and "C3, P3, T4" band 2 (B2): "C2, P2, T4" and band 1 (B1): C1, P1, T1}.

Table 3: The observed improvement against the expected improvement in different bands: band 3 (B3): C3, P3, T3 and C3, P3, T4; band 2 (B2): C2, P2, T4 and band 1 (B1): C1, P1, T1.

Band, Tn	Observed improvement	Expected improvement (calculated from the formula)
C1, P1, T1	0.020	0.014
C2, P2, T4	0.107	0.111
C3, P3, T3	0.053	0.042
C3, P3, T4	0.080	0.075
AVG (average)	0.065	0.060

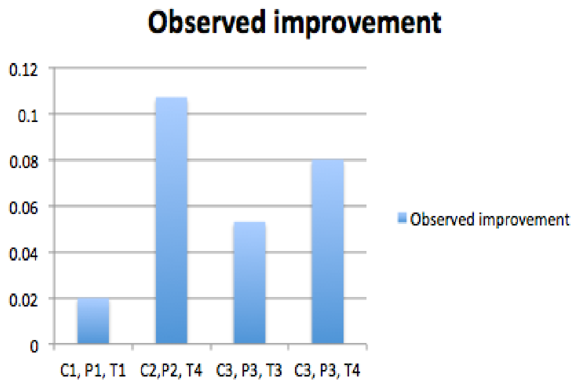

Figure 4. The observed improvement (Y axis) in different bands (X axis): band 3 (B3): C3, P3, T3 and C3, P3, T4" band 2 (B2): C2, P2, T4 and band 1 (B1) C1, P1, T1

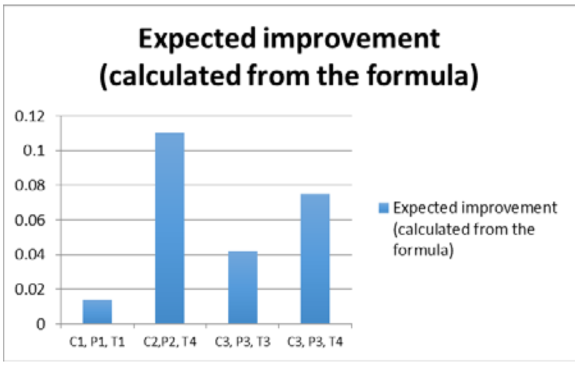

Figure 5. The expected improvement in different bands: band 3 (B3): C3, P3, T3 and C3, P3, T4; band 2 (B2): C2, P2, T4, and band 1 (B1) C1, P1, T1

Table 4 and Figure 6 are showing the average expected improvement (calculated from the formula) and the observed improvement collected from the results of the assessments

Table 4. Average expected improvement (calculated from the formula) and the observed improvement collected from the results of the assessments.

	Observed improvement	Expected improvement (calculated from the formula)
Average	0.065	0.060

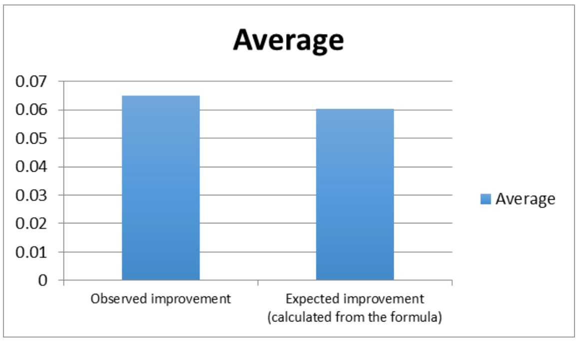

Figure 6. Average expected improvement (calculated from the formula) and the observed improvement as shown in table 4

3.4. The Usefulness and Contribution of the CPT Model

1. The developed model (CPT) can predict the likely learning outcomes for students' progress.
2. The potential impact of this research will be felt predominantly by curriculum designers and policy makers, by allowing predict in advance outcomes of various learning scenarios.
3. This model can be developed in the future by the collaboration of (at least) Education, Psychology, and Mathematics., If it proves useful, then the model will help the educators to improve their students' level and performance by choosing the proper CPT strategy that is suitable for each group of students designed to meet their needs and maximize the learning.
4. By testing across a range of subject areas it may be possible to integrate different levels of technology to maximize learning outcomes
5. This model can be considered, as an entrance for a new research area that can be called the mathematics behind education.

4. Conclusion

At the group level, this pilot study has shown that a pseudo-vector space, where the resultant vector is taken to be the learner progress, can have predictive power. As demonstrated in the collected data which is shown in this paper. This pilot study has further shown that the integration of mobile technology into the learning environment has a positive effect on the learning outcome. As demonstrated in Tables 2&3. Furthermore, by validating the developed CPT model curriculum developers will be able to predict the likely outcome, at the level of the group, based on the level of content, pedagogy and technology. CPT model can be considered as an entrance for a new research area that can be called the mathematics behind education.

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