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Sustainability at Scale: Evidence based recommendations for Teacher Professional Development

Jayakrishnan WARRIEM*, Sahana MURTHY & Sridhar IYER
IDP in Educational Technology, IIT Bombay, India
*jayakrishnan.m@iitb.ac.in

Abstract: Sustainability of teacher professional development (TPD) efforts is difficult to measure due to various contextual and operational issues. The problem is compounded when TPDs are implemented at scale. This paper describes the design and implementation of one such large-scale teacher professional development program – Educational Technology for Engineering Teachers (ET4ET). Two considerations used in the program design, *immersivity* and *pertinency,* help in identification of substitute indicators towards sustainability. Results of measurements show that ET4ET training environment is highly active and participants found the content relevant for their immediate practice, thereby ensuring immersivity and pertinency. Thematic analysis of a post-workshop open-ended survey response by 60 participants, after a semester of their instruction, showed that they had experienced positive changes at three distinct levels – teachers' own level, students' level and institution level. Such positive changes have been known to be good predictors of sustainability. The design and implementation experience along with the evidence helps us to conclude that sustainability has to be a continuous driver for large-scale TPD programs, and the design considerations of immersivity and pertinency will help in sequencing the teaching-learning activities within such large-scale programs.

Keywords: Teacher Professional Development, Sustainability, Large Scale, Design, Pertinency, Immersivity

1 Introduction

Transfer of learning into actual practice is a desired goal of any teacher professional development (TPD) program (Kirkpatrick, 1994; Steinert et. al., 2006). The lasting continuation of learning benefits through practice, even after the end of program is identified as sustainability within the teacher professional development literature (DEZA, 2002). Sustained practice from the teacher and support during the practice (Neilsen, 2015) are key to sustain program benefits even after its end.

Sustainability of TPD is reported through the measures of changes in teachers' knowledge, belief and practices done via interviews or survey questionnaires (Henderson, 2007; Zehetmeir, 2015). Other measures include making classroom observations of teachers' practice and analyzing the teaching artifacts (Bierman et. al., 2013). To ensure reliability of results, program evaluators have to make multiple measurements of these metrics longitudinally. However, when TPD programs are developed and implemented at scale, such measurements become difficult either due to lack of material, financial and personal resources (McLaughlin and Mitra, 2001; Hargreaves, 2002) or due to contextual factors like organizational churn or teacher turnover (Shear & Penuel, 2010). Borrowing from the studies on ecological sustainability (Hák, Moldan & Dahl, 2007), a possible solution to this problem is the use of substitute indicators right at the time of program ideation (Penuel & Fishman, 2011) through metrics available in program effectiveness research.

This paper explains the design of a large-scale, geographically distributed and blended professional development program, Educational Technology for Engineering Teachers (ET4ET)"(Murthy, Iyer & Warriem, 2015). The current paper introduces the design considerations of *immersivity* and *pertinency* substitute indicators of sustainability within the program. These design considerations not only help in design of individual sessions but also aid in keeping sustainability as an inherent goal within the large scale implementation.

The ET4ET program utilized three technology mediums for facilitating learning – A-VIEW (Anand et. al., 2014), Moodle and Wiki, and had 4381 registered participants from 148 different colleges. The measures of immersivity showed that workshop design had kept the participants active and engaged with the session contents with 51% of the session time devoted for active learning strategies. In terms of assignment submissions, more than 81% of participants had submitted at least an assignment and more than half of them had 80% sustained submissions. The measures of pertinency indicated strong correlations ($p=0.000$) between participants' perception of relevance and intention to apply technology and strategies learnt in the program. The pedagogic strategies had found more intentions to apply (over 80%) compared to the technology based strategies (over 70%). Thematic analysis of open-ended survey responses, by 60 participants, after a semester showed that teachers were seeing benefits of the program at three levels – At teacher's own level, at their student's level and within their institution, and were keen on sustaining the efforts.

Our experience with design and evidences from ET4ET experience has provided us with valuable insights on the sustaining effects of large-scale TPD programs. We recommend that any TPD program should have sustainability as an explicit driver and program designers should plan for it at the time of program ideation itself. We also recommend the use of design considerations of immersivity and pertinency, to sequence the teaching-learning activities within such large-scale professional development programs. Using these substitute measures of sustainability, administrators and policy makers can make better-informed decisions on further refinements to the TPD by analyzing the trends of these indicators.

2 Indicators and Design considerations for Sustainability

Sustainability is identified as a central challenge for scaling up educational interventions (Coburn, 2003). The professional development literature contains various definitions of the term sustainability, with the most prominent ones being those related to long-term continuation of benefits even after termination of the program (DEZA, 2002). Measurement of these benefits are not comprehensive as they can occur either at an individual level (Hargreaves and Fink, 2003) or at the system level (Fullan, 2006) and relate to multiple dimensions of teaching and learning (Antoniou & Kyriakides, 2013).

Researchers have used measures related to change in teachers' knowledge, beliefs and practices as a first indicator to report sustainability. These measures are done repeatedly across time using interviews or survey questionnaires (Henderson, 2007; Zehetmeir, 2015) or by making classroom observations of teacher practice and analyzing the teaching artifacts (Bierman et. al, 2013). Another possible measurement is at the level of students by looking into student behaviours and learning outcomes (Cochran-Smith & Zeichner, 2005). While scaling up, such repeated measurements become difficult either due to lack of material, financial and personal resources (McLaughlin and Mitra, 2001; Hargreaves, 2002) or due to contextual factors like organizational churn or teacher turnover (Shear & Penuel, 2010).

Thus professional development program designers who intend to measure the sustainability of scaled up programs are faced with twin challenges of lack of comprehensiveness and difficulty in taking large-scale measurements with currently used metrics. A possible alternative is the idea of using substitute indicators, as is practiced in ecological studies (Hák, Moldan & Dahl, 2007), right from the start of program ideation (Penuel & Fishman, 2011). A characteristic feature of these substitute indicators should be its ability of communicating relevant information to multiple stakeholders and ability of real-time measurements (Hák, Moldan & Dahl, 2007).

Teachers' perception of positive effects during professional development has been identified as a predictor of sustainability (Scheirer, 2005; Hann & Weiss, 2005). In order to achieve these positive effects, it is important that the program have high teacher engagement, active learning during the program, teacher learning, relevance to practice and changes in teachers' beliefs and attitudes (Desmione, 2009; Wells, 2007; Korthagen, Loughran & Russell, 2006; Steinert et. al, 2006). Hence we introduced two considerations into our TPD program design – *immersivity* and *pertinancy*, which are built upon the above existing ideas of program effectiveness and are used as substitute indicators of sustainability.

Immersivity is defined as the feature of the learning environment that drives participants to be involved in a set of meaningful activities (Howland et. al., 2012) and to get cognitively engaged in the content (Sherman & Craig, 2003). Immersivity is built upon the need for having active learning within

the training environment (Desmione, 2009) by adding the concept of immersion (Calleja, 2007), prevalent in the virtual reality and gaming literature. Pertinency of teacher training content is defined as the training participant's perception of degree to which the given content is applicable for his/her teaching immediately after the training. This idea builds upon the element of job relevance (Venkatesh & Davis, 2000) by adding the constraint of immediate practice. It can be seen that both these design considerations of immersivity and pertinency provide sufficient measures such as engagement, activeness, perception of relevance and perception of immediate application, to make them amenable for real-time measurement and subsequent trend analysis that is crucial in a large-scale implementation. Immersivity is measured through frequency and student engagement in the designed activities within the learning environment, while pertinency is measured through perception of relevance and intention to apply and the correlation between the responses. Detailed operationalization of the constructs are discussed within section 3.3 and 4.2.

In the next section we describe the implementation of these design considerations within the ET4ET program.

3 ET4ET Program

3.1 Background

The Teacher Professional Development program presented in this paper was conducted for the project "Teach 10 Thousand Teachers" (T10KT, 2015) which runs under the national initiative of the Indian government, National Mission on Education through ICT (NMEICT, 2015). The T10KT project runs 2-4 weeks workshops on various engineering topics, with a goal of enhancing teaching-learning skills of engineering college faculty. The workshops uses the A-VIEW software (Anand et. al., 2014) to stream instructions synchronously from a central hub to several remote centers that are also called as synchronous remote classrooms (Warriem, Murthy and Iyer, 2013). Several participants come together and attend the workshop from any of the 200+ remote classrooms across India, based on their physical proximity to these locations. The courses under T10KT handle assessment of participant through quizzes and assignment submissions in Moodle.

Educational Technology for Engineering Teachers (ET4ET) is a series of TPD programs intended for improving the teaching-learning skills of engineering college instructors in integrating technology in classrooms (Murthy, Iyer & Warriem, 2015). ET4ET is based on the A2I model for design and implementation (Warriem, Murthy & Iyer, 2014). The program discussed in this paper, second in this series, was run in a blended format, where synchronous sessions were conducted through A-VIEW in two phases, with an asynchronous session facilitated via Moodle separating them. In addition to A-VIEW sessions and Moodle based evaluations in T10KT, ET4ET participants also had to contribute in a Wiki (Wikifortrial, 2015). Figure 1 shows the multiple learning environments and the interactions within the ET4ET implementation.

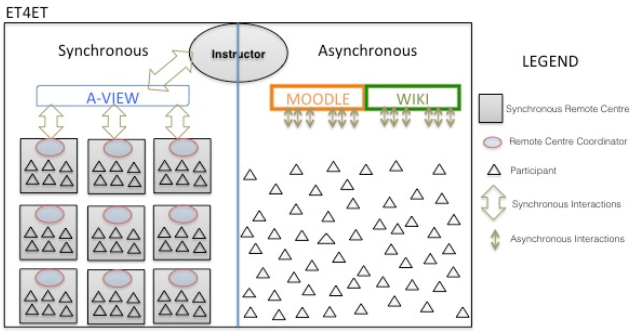

Figure 1: Implementation of ET4ET across multiple learning environments

3.2 Implementation of ET4ET

ET4ET ran for a total of 4 weeks duration in January, 2015 in a blended mode, with an effective instruction time of 2 weeks. A total of 4358 participants attended this program from 148 remote centers.

Figure 2 shows implementation of 6 days of synchronous instructions with lab sessions sandwiched between an asynchronous phase and the relevant assignments. Each day consisted of a total 4 sessions and the learning environment used in each session is shown in the figure. In the synchronous phase, participants worked through in a number of active learning strategies such as Peer Instruction and Think-Pair-Share conducted via A-VIEW. They also learnt how to use technology-based teaching-learning strategies such as Flipped Classroom and Wiki. In the lab and asynchronous sessions they use Moodle and Wiki environments.

There were 10 A-VIEW sessions and 10 Lab sessions spanning across 5 days. The participants had to submit 10 key assignments across these sessions to demonstrate their learning. As seen from figure 2, there is a high focus on participant engagement with content through lab sessions during each day of the Phase 1 and Phase 2 of the workshop. In terms of time, 11.5 hours (43%) of total Synchronous sessions were devoted for labs.

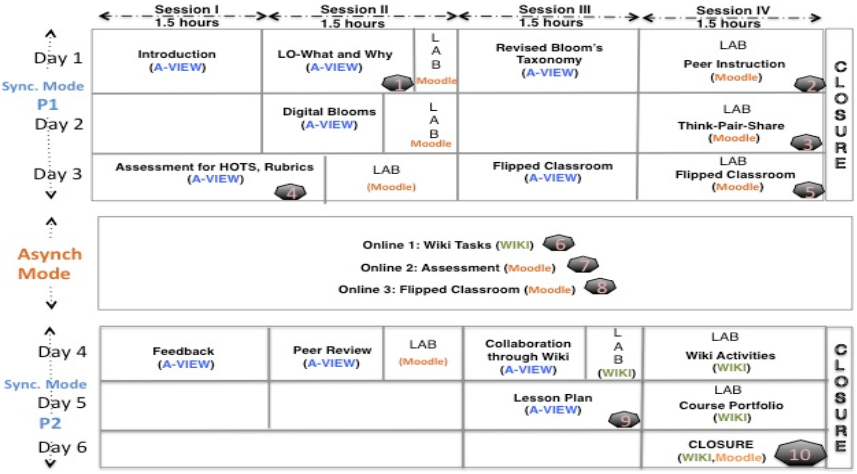

Figure 2: ET4ET Implementation details

3.3 Immersivity and Pertinency in ET4ET

We assured immersivity in ET4ET by:

- Designing sessions in which participants first approach the strategy as a student and then as teachers. For example, we first conducted Peer Instruction strategy within our sessions on Day 1 where participants experienced the strategy as students. Later within the Peer Instruction Lab they created Peer Instruction questions for their own students.
- Ensuring participants perform a concentrated activity using technology before learning about technology. For example, participants first performed concentrated activities on Wiki from asynchronous phase before learning about Wikis on Day 4.

Both these design decisions promoted immersivity because participants become more familiar with these strategies/technology through initial practice before actually trying to create similar strategies for their own classroom (Murthy, Iyer & Warriem, 2015). To measure immersivity in ET4ET, we used participant engagement measured across the three mediums of A-VIEW, Moodle and Wiki.

We assured pertinency within ET4ET by:

- By using extensive examples from the participants' own domains while discussing teaching strategies within the synchronous sessions. For example: for participants from the domain of electrical engineering we had set up examples related to Logic Gates and Ohm's Law across the sessions.
- By asking the participant to work on assignments in a topic they will teach in the coming semester.

To measure pertinency, we had conducted an open-ended surveys based on constructs of relevance and intention for immediate practice.

4 Research Method

4.1 Research Questions

The broad research question that we investigated is: Does the large-scale implementation of ET4ET program design lead to sustainable teaching-learning practices of Indian Engineering instructors? To answer the above question, we examined three specific research questions (RQ):

- RQ1: How pertinent is the ET4ET program?
- RQ2: How immersive is the ET4ET program?
- RQ3: How has the participants' learning from the ET4ET program transferred into actual practice?

4.2 Data Sources and Analysis Techniques

Data was collected at three different time points within the program: During design, during implementation, immediately after the program. Another set of data was collected after a semester of instruction at participants' colleges. The details of the data sources and the measured metrics are summarized in Table 1 below.

Table 1: Data sources and sample for the study

Constructs Measured	Data Source	Metric
Immersivity	Video sessions and slides (ET4ET, 2015), Program Schedule	Time spent during the program on active learning activities
	A-VIEW Chat logs	No of chat interactions to Active Learning strategies.
	Moodle	Active learners based on assignment submissions
	Wiki	Number of page views, edits and user statistics
Pertinency	End of program feedback survey	Perception of relevance and intention to apply. Correlation between two perceptions.
Transfer to Practice	Open ended response to survey after a semester	Levels of Changes observed

From section 3.3, we see that immersivity is measured across 3 different environments – A-VIEW, Moodle and Wiki. Hence there were multiple data sources and varying sample sizes for each of the measures. As seen in section 2, immersivity is defined as participants' involvement in meaningful activities (Howland, 2012) and resulting cognitive engagement. Within the A-VIEW environment these are measures related to the designed active learning strategies, i.e., time devoted for the strategies and chat responses relevant to these strategies. In the Wiki environment user involvement is measured through the user statistics of page creation and page edits. In Moodle, there were 10 assignments designed for cognitive involvement of the participant, and we have used the number of assignment submissions as a direct measure of immersivity.

From section 3.3, we see that pertinecy is a measure of self-perception on relevance and intention for immediate practice. We have measured pertinency by using survey questions that had a 5-point Likert scale, administered via Moodle. The survey had 8 questions relating to relevance and intention to apply the pedagogic practices of Peer Instruction and Think-Pair-Share and technology-based strategies of Flipped Classroom and Wiki. Sample questions about Peer Instruction strategy was "The lab session and activities on Peer Instruction (PI) were highly useful for me to plan PI activities on my own" and "I intent to use Peer Instruction in my course in the coming semester". On calculating Cronbach's alpha, we found that questions related to pedagogic strategies had an acceptable reliability measure of 0.764 and that of technology-based strategies also showed acceptable value of 0.742. The survey received 1202 responses, and the frequencies of these responses were then analyzed and Spearmann's correlation coefficient was calculated.

To understand the changes in teacher's practice after the program, we had administered a survey, via Moodle, after a semester of instruction of the participants in their own colleges. The survey had an open ended question "Overall what changes do you feel in your teaching in this semester after attending the Pedagogy Workshop?" 60 participants had responded to this survey and we had performed a thematic analysis of these responses. While doing the thematic analysis we had followed the steps mentioned by Braun and Clarke (2008), wherein two researchers had used a deductive approach based on the existing literature on different levels of program effectiveness (Kirkpatrick, 1994; Steinert et. al., 2006). Two rounds of coding by both the researchers generated the initial codes and these were clubbed further to generate common themes. The themes were then reviewed once again before refining it a level further and generating three broad common themes related to changes observed at Student Level, Teacher Level and Institution Level. For example, initial codes of student learning, student belief and student practice were clubbed together to form the theme "Changes in Student" which was further refined to "Changes at Student Level".

5 Results

5.1 Immersivity in ET4ET implementation

Table 2: Active-learning strategies and resulting engagement in A-VIEW

		Day I		Day II	Day III		Day IV		TOTAL
Design of ET4ET	Session	2	3	2	1	3	1	3	
	Time in min for AL (Session %)	31 (34%)	30 (33%)	29 (32%)	47 (52%)	30 (33%)	44 (49%)	5 (17%)	216 (51%)
Implement -ation of ET4ET	No of AL activities	4	4	7	11	3	6	2	37
	No of Chat messages	347	427	1336	1090	492	874	227	4793

The immersivity of ET4ET implementation is observed in all the three learning environments, i.e, A-VIEW, Wiki and Moodle. We see that within the A-VIEW sessions there were sufficient amount of active learning strategies that kept the participants engaged. The evidence for the engagement comes from the chat messages received in the A-VIEW sessions during each of the strategies. From Table 2 above, we see that 37 active learning strategies were used across the 7 sessions that totaled to 3.5 hours of active engagement (or 51% of instructional time). In terms of remote center participation, we see that the average interaction per strategy is 130, i.e. 87.8% of remote center participation.

The participants were provided with 8 Wiki tasks that required them to create 4 different Wiki pages per person and 1 page per remote center and perform at least 10 edit operations. It was seen that over the course of the program, 1009 different participants had generated 6279 pages and performed 21487 edits. With respect to the 3551 synchronous session participants, the participation rate in Wiki had dropped down to 28%. However, in terms of activity presence within the Wiki we can see that participants have created an average of 6 pages per person and performed 21 edits per person. In terms of remote center presence, participants from 59 different remote centers (40%) were active in the Wiki.

Participants used Moodle for accessing resources, attempting the "Moodle Lessons" and submitting assignments. Since our focus is the engagement of participant with the content, we look at the number of assignment submissions across the program. We look at the submissions of active learners, i.e. people who have submitted at least one, and look at the sustenance with respect to them. It can be seen from Figure 2 that the numbers were much more than half for more than 80% of the workshop assignments. 30% among them submitted the final assignment. It can also be seen that, barring the second assignment, there is consistent trend of attrition of active learners across each phase.

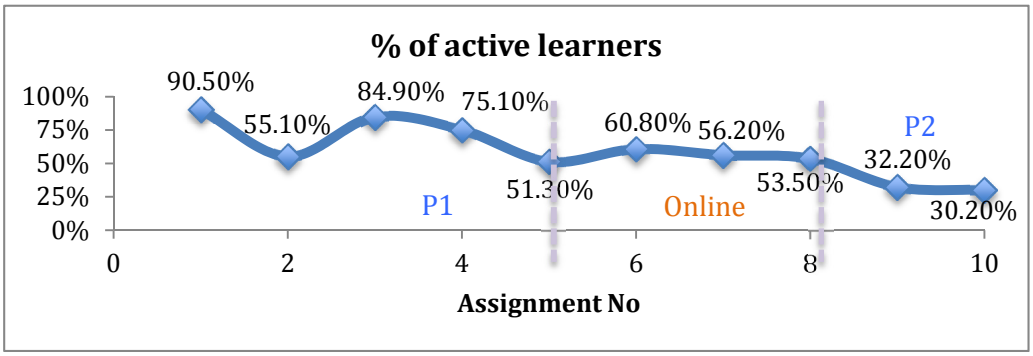

Figure 2: Percentage of active learners as measured from Moodle assignment submissions

5.2 Pertinency in ET4ET implementation

The analysis of responses to the post-program survey are shown in Figure 3 below. We see that there is a uniform high perception about relevance and intention to apply both strategies and technologies. The analysis of survey responses further shows strong positive correlation (p=0.000) between relevance and intention to apply the technology (ρ_{FC} = 0.464, ρ_{Wiki} = 0.507) and strategies (ρ_{PI} = 0.435 and ρ_{TPS} =0.481). It is seen that more than 84% of respondents indicated positive response towards relevance of Think-Pair-Share and Peer Instruction strategies while the ratio became 82% and 79% for Flipped classrooms and Wiki respectively. The intention of applying Think-Pair-Share as a strategy was found to be highest at 88%, while intention of applying Wiki was found to be the least at 70%.

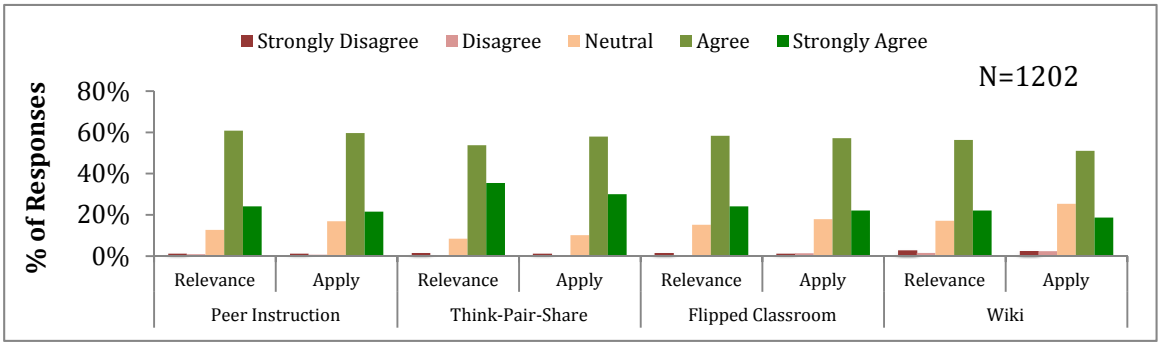

Figure 3: Participant response to Relevance and Intention to Apply

5.3 Teacher self-reports on changes in practice

The post workshop survey administered received 60 responses from 27 different colleges, which are representative of the diversity observed in the workshop.

Thematic analysis (Braun & Clarke, 2008) of the open-ended responses has revealed three broad themes about which effects of the program were observed: Effects at student level, effects at teacher level, and effects at institution level. The first theme of interest is the changes observed at student level. Most of the respondents felt increased engagement of the students and its effect on the student learning. This is best highlighted by the comment *"I was able to engage the backbenchers with the activities and that was reflected in their exam results."* The teachers also felt that applying workshop learning has facilitated better learning attitudes and beliefs from students, as is evident from the comment *"Students are more focused about the Learning Objectives"*, and *"students are more aware about what is being taught for what purpose."* Comments like *"My students were able to answer those questions which was not discussed in detail"* indicated a positive perception towards students' learning practices after attending this workshop.

At the teacher's level, they have indicated changes in beliefs and attitudes, and practice. The attitude shift from a teacher-centric or content oriented approach to a more a student centric or learning oriented approach is quite evident. Comments like *"[I was] Thinking from a student perspective rather than a teacher perspective"* or "*The teaching becomes more focused to [student's] learning objectives"*

bear evidences for the same. Some participants indicated improvement in self-belief as seen from comments like *"I feel I can handle the class with more confidence"* and *"... able to apply learnt practices, hence feeling happy"*. They also feel that their practices have improved to make classes more interactive and engaging and that is indicated from the comment *"In each class I am successful in grabbing the attention of every student in the class by making them to involve in one or the other activity."* There was a comment on the evaluation activity, where the teacher had mentioned, *"[Question] Paper setting is improved after attending the workshop."* The comment *"... ICT enabled teaching methodology will be fruitful in future if we follow it regularly"* brings out the need to sustain these practices to bring about positive changes.

At the institution level, two teachers clearly indicated the explicit effort made by them to disseminate the learning from workshop. A teacher had commented *"we also conducted a training program for about 120 faculty members out of 350 in our College and shared the important topics of this workshop."* This teacher indicated their plan to sustain this effort - "*We have also planned to conduct another phase of this workshop to convey all the topics in the near future.*"

6 Discussion

The high amount of active learning and engagement of the participants across the three learning environments, as seen in section 5.1, indicates that ET4ET has been highly immersive (RQ1). An important immersivity feature that has resulted in such high engagement is the design consideration of letting the teacher experience the strategy as a learner first (Korthagen, Loughran & Russell, 2006). This combined with the higher pertinency measures of these pedagogic strategies leads us to believe that participants have experienced sufficient positive effects to sustain the use of these pedagogic strategies within their classrooms (Scheirer, 2005; Hann & Weiss, 2005). The attrition of active learners across the program, as seen from the assignment submissions, is quite common among such large-scale programs (Clow, 2013). However the sustenance of more than half the learners for 80% of the assignments is comparable with the earlier implementation of ET4ET (Murthy, Iyer and Warriem, 2015), even though the current implementation had four times more registered participants.

The high measures of relevance of contents and its significant correlation ($p=0.000$) with intention to apply, as seen from section 5.1, indicates that ET4ET was highly pertinent (RQ2). It is seen that participants have high intention to apply classroom-strategies, like Think-Pair-Share (88%) and Peer Instruction (84%), more than purely technology-based strategies like Wiki (70%). One possible reason could be the challenges to lesson design with technology observed by instructors in technology-constrained classrooms, that are prevalent in the context of the ET4ET program (Banerjee, Murthy and Iyer, 2015).

Thus the evidence points to the fact that design considerations of immersivity and pertinency will be helpful both in measuring the indicators of sustainability and design of the professional development program. The TPD program design includes the sequencing of teaching-learning activities as well as the examples being considered within each session or assignments.

The open-ended survey responses, after a semester of instructions, show that the participant teachers had felt changes in practice at three levels – Student's level, Teachers own level, and Institution level (RQ3). It is seen that the high engagement and interaction felt by participants in ET4ET is also observed in their own classrooms. A few of them have started disseminating the program knowledge within the institution at a large scale. This is indicative of the high positive effects felt by participants at multiple levels (Stes et. al, 2010), which in turn is a good predictor of sustainability (Scheirer, 2005; Hann & Weiss, 2005).

Since sustainability has been measured using metrics of Immersivity and Pertinency across the program implementation, it helps in minimizing the operational and contextual barriers (McLaughlin and Mitra, 2001; Hargreaves, 2002) associated with measuring sustainability. Within the context of the T10KT, it can be seen that these indicators convey multiple relevant information to various stakeholders associated with it (Hák, Moldan & Dahl, 2007) thereby increasing chances of making informed-decisions on sustaining the program effects. At an individual level for the teachers (Hargreaves & Fink, 2003), the indicators convey the high engagement and relevance of the program contents in their practice. At the system level (Fullan, 2006), indicators provide valuable information to college administrators, T10KT project managers and policy makers to take future course of actions. To the college administrators, it reflects the collective participation and engagement of their institution

during the program. To the government and project officials and other TPD designers, the program provides information on desired characteristics of future TPD and their measurement. We believe that actions based on such informed-decisions will increase the possibility of sustaining the effects brought about by ET4ET implementation.

A limitation of this study is that teacher reports on practice were gathered only a semester after the ET4ET implementation. Currently, this only constitutes evidence of short-term sustainability. However, we believe that these results would help in refinement of the ET4ET program design to include additional indicators and practices towards long-term sustainability. Future work includes gathering and analyzing longitudinal data from the ET4ET participants in the next two years. A second limitation is that the substitute measures of immersivity and pertinency are not comprehensive. However, these indicators are useful for administrators and policy makers to make better-informed decisions towards maintaining sustainability of the TPD, especially when the program is conducted at scale. Analyzing the trends of these indicators can help further productive refinements to the TPD.

7 Conclusion and recommendations

In this paper, we have explained the design considerations of pertinency and immersivity for a TPD program that can be used as two substitute indicators for measuring sustainability. We have implemented these design considerations within the ET4ET program, a TPD under the 'Teach 10000 Teachers' project of the Indian government's National Mission on Education through ICT. We have observed high immersivity and pertinency with the TPD, and seen that it has translated into sustainable changes at three levels – Teacher's level, Students level and Institutional level.

Insights from our design and implementation have led us to conclude and recommend that: i) Sustainability needs to be a continuous driver of TPD right from ideation phase, and ii) Design considerations of immersivity and pertinency should be used in sequencing the learning experiences of teachers within the training environment, particularly when TPD is done at scale. Immersivity can be assured by providing sufficient active learning activities within the training and ensuring that teachers perform concentrated activities first as a student. This can then be evaluated by measuring the participant engagement across the training environment during the activities along with frequencies of final submissions. Pertinency can be assured by ensuring that participants are provided with examples from their own domain and exercises related to the subject they are teaching.

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