A Study Examining the Development of STEM Inquiry-Based Pedagogies With TVET Education Lecturers: An International Professional Development

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Abstract
The National Standards Curriculum implemented in 2016 in Jamaica includes expectations that STEM disciplines be integrated into the primary and grades 7-9 curriculum. This integration is framed on an inquiry-based model driven by problem-based and project-based learning. Lecturers therefore need to know about STEM integration and how to model this to preservice teachers. This paper reports on an international collaboration between faculty from a university in Jamaica and Canada respectively, who facilitated a STEM professional development (PD) summer institute in June 2022 for lecturers teaching in the Technical and Vocational Education and Training (TVET) program at the Jamaican university. The study examined the lecturers' experiences (n=22) and the knowledge gained about STEM inquiry-based pedagogies and integration in TVET contexts. Data sources included a questionnaire on demographics and teaching practices, photographs and short video segments from workshops, written feedback after each workshop, and a workshop evaluation at the end of the three days. Findings indicated that participants found the workshops effective with respect to presentation and sequencing over the three days. Participants also indicated that workshops were effective at communicating knowledge about STEM instructional approaches which would be useful to them as TVET teacher educators. Findings contribute to the modest literature on faculty PD and international collaborations and provide insights on PD for lecturers to learn how to integrate STEM approaches in preservice courses. The study also provides a model for capacity building of faculty pedagogy in Teacher Education and contributes to capacity building of a workforce for STEM fields in Jamaica.

Keywords: Teacher Educators, Professional Development, STEM, TVET, International Collaboration

Introduction

In Jamaica, The National Standards Curriculum 2016 places emphasis on Science, Technology, Engineering and Mathematics (STEM) approaches, Information Communication Technology (ICT) integration, and Inquiry Based Learning (IBL) to promote skills such as critical thinking, collaboration, communication, creativity, and problem-solving in the grades K-9 curriculum. Technical and Vocational Education and Training (TVET) skills were also integrated across grades 1-13. As such, Jamaican teacher education institutions are to prepare pre-service teachers to be able to integrate STEM pedagogies such as project-based learning and engineering design into the primary and grades 7-9 TVET curriculum. TVET lecturers therefore need to know about STEM pedagogies and how to model and integrate these pedagogies in their preservice courses. Research indicates that there is a relationship "between the amount of faculty development and improvements in teaching" (Rutz et al, 2012, p, 43). Professional development in educational contexts may be conceived,

> as structured, facilitated activity for teachers intended to increase their teaching ability. The focus on teaching ability is intended to include a broad range of skills including instruction, classroom management, assessment, and lesson planning. (Sims at al., p. 7)

Sims et al. (2021), in a comprehensive meta-analysis of teacher PD, found that effective PD interventions are those that align with a schools' needs and practices, and take into consideration the limited time teachers have. These factors also apply to university faculty/lecturers who buy-in to PD when they perceive the PD is aligned to their teaching goals, fit into their schedules, and contribute to professional scholarship goals (Jaipal-Jamani et al., 2015). A few studies have conducted research on faculty PD. Manduca et al. (2017) investigated a national geoscience PD program and found that faculty transfer of workshop learnings to teaching practice was supported by: 1) availability of resources (e.g., online) to support and facilitate transfer of workshops learnings and 2) discussions with colleagues during the workshops which motivated faculty and increased their confidence to incorporate changes into their teaching. Qualitative data in the Manduca et al. study suggested that even attending one workshop with colleagues can lead to changes in teaching practice as it supported affective (e.g., changes in beliefs and increased self-confidence and self-efficacy) and cognitive learning outcomes (e.g., developing metacognition and reflection on practice). Meijer et al. (2017) also found that self-study interventions with teacher educators, guided by trained facilitators, did support positive changes in faculty beliefs and teaching practice.

The purpose of this study was to gain insights into lecturers' experiences and the knowledge gained about STEM/TVET pedagogies as they participated in a STEM/TVET summer institute. The following questions guided the research:

- What were lecturers' evaluations of the design of the professional development workshops?
- What were lecturers' perceptions of the usefulness of the knowledge and STEM workshop activities for implementation in their courses?

Theoretical Perspective

A current trend in higher education over recent decades has been a move from instructor-centred teaching or lecture style pedagogy to the inclusion of more student-centred learning or active learning pedagogy (Hoidn & Klemenčič, 2021). This shift has been informed by views of learning as the making of connections between prior knowledge and new knowledge to construct a more meaningful understanding of the new knowledge (Doyle & Zakrajsek, 2019). This shift in teaching pedagogy has been reinforced by neuroscience research that shows it is only when a person does “the practicing, reading, writing, thinking, talking, collaborating, and reflecting does [the] brain make more permanent connections” (Doyle & Zakrajsek, 2019, p. 18). The integration of active learning strategies such as think-pair-share and small group peer discussions in lectures has been shown to support the development of meaningful and more permanent connections among information that can be transferred in new ways (Hoidn & Klemenčič, 2021). It has also been shown that using multiple senses to interact with new information helps the learner to construct a better representation of the concept or idea (Medina, 2008, Shams & Seitz, 2008). Di Napoli and Geertsma (2020) have used active learning as a conceptual framework to design educator professional development (PD) where “active learning as a conceptual framework encourages interactions, integration and innovation based on informed reflections, feedback and collective knowledge and practice building”(p. 487). They found that to effect meaningful change in teachers’ conceptions of teaching and learning that encourage experimentation of and implementation of student-centred approaches in practice, “it is imperative for teachers to discuss not only their teaching, for which a shared pedagogical language is needed, but also to discuss the evaluation results of their teaching that go beyond feedback from students” (p.287).

In this study, we incorporated active learning strategies in the problem-based and engineering design activities for the three-day STEM summer institute. This design encouraged faculty to engage and participate in constructing knowledge, questioning, sharing ideas, doing and reflecting on activities, ideas, perspectives, and giving and receiving feedback. We also provided support such as a STEM planning template to lecturers to guide their planning of follow-up action research in their teacher education courses. This paper presents results on the faculty learning during the three-day summer institute.

Research Context and Methods

The PD was facilitated by two science educators from Canada and one teacher educator from Jamaica. An email invite was sent out to all lecturers in the TVET department at the Jamaican university to attend the STEM PD summer institute over three days. About 25 participants (including lecturers teaching TVET and education courses and a few PhD students) attended the workshop each day over the three days. The workshops focused on STEM problem solving approaches and were linked to objectives in the Jamaican Resource and Technology Curriculum, grades 7, 8 and 9 to illustrate examples in TVET contexts. The Jamaican National Standards Curriculum also requires learning experiences (lessons and units) be structured using the 5E Instructional Model (Bybee, 2014). The workshops introduced inquiry-based learning and problem-solving strategies in STEM such as project/problem-based learning, engineering design, and scientific inquiry. Examples of workshop instructional activities included a STEM design challenge, makerspace stations to create artifacts such as a light up greeting card (Industrial Techniques grade 7 curriculum module), a hydroponics system (Agriculture and Environment grade 8 curriculum module) and a multi-purpose fashion garment/item (Fashion and Textile grade 9 curriculum module). A robotics workshop was also facilitated in the computer lab to introduce programming with LEGO WeDo and Scratch to illustrate how STEM/STEAM objectives can be met. All workshops were followed by a debriefing and reflection session where participants engaged in a pedagogical discussion of the activities in relation to the curriculum outcomes and reflected on how they would design the activity using the 5E model for lesson planning. For each activity and follow-up debriefing, handouts and templates were provided to guide the activities and discussion. A handbook was created and provided electronically to each participant after the institute to support transfer of activities into practice.

The data sources for the PD program evaluation were a pre-questionnaire on demographics and teaching practices adapted from previously validated science teacher surveys (Hayes et al., 2016), written feedback after each workshop, and a post workshop evaluation filled in on the third day (adapted from Jaipal-Jamani et al., 2015). Findings related to the effectiveness of the workshops were triangulated using additional data such as photographs of workshops and observational field notes made by the researchers/facilitators. The workshop evaluation comprised 8 questions: the first three questions were on the effectiveness of the timing and pacing, presentation of information and sequencing of information; the final 5 questions elicited responses on the effectiveness of the STEM strategies and application in university teaching on a Likert scale of 1 (strongly disagree) to 4 (strongly agree). This evaluation was used to obtain descriptive quantitative feedback and was not validated statistically.

Results

Demographic data from workshop participants are reported below in Table 1. 59% of lecturer participants had over 10 years of teaching experience; 40 % taught preservice courses related to curriculum foundations, special needs, psychology and ICT while the rest of the lecturers taught their TVET specializations such as food and fashion and industrial technology. Since this was a TVET program, 45% of lecturers indicated that they integrated STEM often while 35% indicated that they integrated STEM sometimes in their courses. Over 70 % of lecturers incorporated inquiry-based learning in their courses either often or in almost all classes,

	Likert Scale/Choices/Fill in the blanks				
Full-time teaching experience n=22	0-5 years	6-10 years	11-20 years	Over 20 years	
% Response	27%	14%	36%	23%	
Course Taught n=20	Business	Industrial technology, construction and architecture	Food and Fashion	Electronics/ control systems	Curriculum, psychology, special ed, research, educ. foundations, ICT
% Response	10%	15%	25%	10%	40%
Frequency of STEM integration n=20	never/ rarely	Sometimes	Often	almost all classes	
% Response	10%	35%	45%	10%	
Engage class in inquiry learning through problems and projects	never/ rarely	Sometimes	Often	almost all classes	
% Response		27%	46%	27%	

Table 1: Demographic Information

Results of the workshop evaluations indicated that of the 16 participants who responded, over 80% of participants found the timing and pacing effective to very effective and 100% of lecturer respondents found the presentation of information and sequencing of information to be effective to very effective. Table 2 indicates the percentage of respondents who agreed or strongly agreed for items 4-8 on the workshop evaluation.

The workshops were effective at communicating knowledge about STEM instructional approaches	94%
The workshop was effective at communicating knowledge about engineering design in TVET contexts	94%
The information presented was useful to me in my role as a teacher educator	94%
I have gained knowledge that I will be able to easily implement in my university teaching practice	75%
The PD has provided me with practical applications and resources that will enhance preservice teacher understanding and engagement in STEM pedagogies	81%

Table 2: Lecturer responses in workshop evaluation: agreed or strongly agreed.

The findings from table 2 indicate that the workshops were very effective at communicating knowledge about STEM instructional approaches which would be useful to them as teacher educators. Comments from some qualitative data collected during the workshops aligned with survey results. For example, one lecturer commented; "*The exposure in workshops will enable me to prepare student teachers to introduce STEM approaches in their lessons and gave me an insight in evaluating the students as they deliver STEM lessons.*"

Further insights on the workshop experience were obtained from reflections by lecturers on how they might implement STEM/TVET strategies and the constraints and challenges they might experience. For example, one lecturer commented how the nature of the course and time would affect implementation: "*While the strategies are effective, they may not necessarily be easy to implement in my university teaching mainly because most modules are heavily content based and must be completed within a specific time frame.*" Lecturers also indicated specific knowledge, strategies and activities they would apply in their practice that they had learned in the workshops. For example, some indicated they would incorporate the 5 E model or use it to develop more effective 5E lesson plans and use the design process; many indicated they would use the hands-on activities, robotics, and the makerspace activities such as Tinkercad and hydroponics. A lecturer also mentioned that they liked the opportunity of learning from each participant's experiences.

Conclusion

The findings show that the hands-on, interactive STEM workshops offered lecturers an opportunity to reimagine their pedagogical design in their teaching. The PD workshops created a space for dialogue and reflection on teaching practices for lecturers who are normally busy with a full teaching load; they were able to come together, learn, reflect and discuss what active learning strategies might require of them as they challenge their practices to consider teaching that is student-centered. The results support Di Napoli and Geertsma (2020) views that meaningful change in teacher practice is fostered by collaborative discussion and reflection among teachers in safe and supportive settings. The findings contribute to the literature on STEM faculty PD and suggests that implementing a three-day, STEM PD program for lecturers did provide them with STEM knowledge about STEM instructional strategies which was useful to them in their roles as teacher educators. Just under half the lecturer participants indicated they rarely or sometimes integrated STEM in courses. Participation in hands-on workshop activities that modelled STEM pedagogy did encourage more lecturers (75% of participants) to indicate they would be able to easily implement the strategies in their practice. A limitation of the study is that the findings are reflective of this unique STEM/TVET context and may not be applicable to other university contexts. The sample size is also small, and findings are not generalizable. Nevertheless, the study provides insights into the design of STEM faculty PD based on an active learning framework and illustrates how STEM workshops can be designed to incorporate active learning strategies to promote student-centered or active learning pedagogy. Workshops should also be followed up with implementation of learning in teaching practice. As Rutz et al. (2012) assert, developing skills that support reflection on teaching from "observations of student learning, is as important as the individual lessons learned in a particular workshop" (p.47). Hence, lecturers were provided with the opportunity to implement workshop strategies in their teacher education courses and reflect on their practice and student learning through action research.

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