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Using Productive Pedagogy to Improve the Teaching and Learning of Practical Numeracy with Adult Learners

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Abstract

In 2001, the Queensland State Government in Australia developed the Productive Pedagogy (PP) framework for teaching that aims at improving students' achievement and engagement in the study of mathematics and other subjects across all school levels. Today, PP is widely used as both a research tool and as a means for self-reflection on practice by teachers. However, little research has been conducted on the effectiveness of PP as a framework in cultures other than the Western world. This paper discusses how 7 elements of the PP were utilised to design student projects in order to enhance the teaching and learning of Practical Numeracy (PN) among young adult Arab women. Data analysis suggests that the adoption of PP framework in this context has helped to improve the teaching and learning of the PN course, has contributed to the increase of the students' engagement in mathematics classes and promoted their active citizenship.

Keywords: Practical Numeracy; Productive Pedagogy; Mathematical Enriched Worksheet

1. Introduction

In many countries around the world, several students disengage from mathematics study because they find it boring and meaningless. Many mathematics curricula and school structures rarely allow for linking of mathematics to other subjects. Further, when attempting to relate mathematics to the real life, such attempts often use artificial contexts of little interest to the students. As a result, many students see mathematics as an isolated subject, with little personal meaning and with no relevance to their lives (Peterson, 2005) besides performing routine financial transactions. If students are provided with the opportunity to investigate real issues in their lives through mathematics, their level of engagement would very likely improve and in the process they would have the opportunity to construct and apply important and powerful mathematical concepts (Atweh & Brady, 1999; Turner & FonStrawhun, 2006).

Several projects around the world have attempted to reform school teaching to make it more relevant to students' and society's needs in a rapidly changing contexts. For example, in its efforts to improve achievement and interest in the study of mathematics and other subjects across all school levels, the Queensland State Government initiated the New Basic Project in 2001 (Department of Education, Training and Employment). The New Basics Projects provided new curriculum organisations, novel assessment tasks, and a framework for designing teaching called the Productive Pedagogies (PP).

This paper discusses how the teaching and learning of Practical Numeracy (PN) course for a group of Arab women was enhanced by the use of project work demonstrating certain elements of the PP framework. The framework pays attention to many important aspects of classroom teaching demonstrated by worldwide research as effective in improving teaching. In other words, PP is not a set of pedagogies or strategies of teaching, but principles that are used to design teaching and to reflect on teaching. It is made up of 4 main dimensions: intellectual quality; connectedness (relevance); socially supportive classroom environment; and recognition of difference. The 4 dimensions are further subdivided into twenty elements. Today, PP has gained worldwide recognition as both a research tool to improve students learning (Hayes, Mills, Christie & Lingard, 2006) and a means for teachers to critically reflect on their practices (Mills, et al., 2009). The 7 elements of PP utilised in this study are: (1) higher order thinking (2) substantive conversation (3) connectedness to the world (4) academic engagement (5) student control (6) student support, and (7) citizenship. These elements span the four PP dimensions in line with Hayes et. al's (2006) suggestion that "at least one item from all 4 dimensions should be present to ensure that the academic and social outcomes of all students are maximized" (p. 77).

2. Theoretical Background and Literature Review

Research evidence demonstrates that an essential factor leading into effective numeracy development is good teaching (ACAL, 2007). The PP framework provides teachers with a comprehensive tool to plan and reflect on their teaching towards increasing students' outcomes. Mills et al., (2009) argued that if the work given to

students is connected to their worlds, a learning environment will be created in which they are most likely to demonstrate high levels of intellectual outcome. Today PP is utilised by many researchers as means for improving students' achievement (Hayes, et. al., 2006). A number of researchers have utilised PP in a variety of contexts. For example, Cronin and Yelland (2004) in their study of numeracy outcome amongst young Australian indigenous children found PP to be a powerful framework in assessing and enhancing their positive numeracy outcome. Similarly, Chinnappan (2006) in his work with a group of beginning teachers found PP provides a useful framework for building an online community of learners in Mathematics Education.

We now turn to a short description of the four dimensions of the PP framework and the specific elements discussed here.

Intellectual Quality: The main thrust here is that if students are to do well at school they must engage in intellectually challenging work regardless of their ability or social background. Enhancing intellectual quality involves teaching which targets relational rather than the instrumental understanding (Skemp, 1976). According to this dimension of PP, students are to experience higher-order thinking in their approach to mathematical problems and the opportunity to communicate and argue their ideas effectively. It also encourages debates to enhance further their understanding of complex concepts. Two elements of this dimension were implemented here, namely; *higher order thinking* and *substantive conversation*. Higher order thinking requires the learners to carry out tasks in which they analyse and synthesise their findings. Substantive conversation requires elaborated discussions between student – student and between teacher – students, which are reciprocal, and which promote coherent shared understandings.

Connectedness (or relevance): Connectedness implies that learners should be provided with the opportunity to engage in activities in which they can see the connection between what they are learning with their previously acquired knowledge and with their life experiences outside the classroom. The taught curriculum should adopt a problem based approach, and be one that helps consolidate and enhance the learner's understanding of their world beyond the classroom. One element of this dimension was implemented. Connectedness to the world requires the tasks in the classroom to have real life connections to the learner's world.

Socially Supportive Classroom Environment: A socially supportive classroom environment should not only be a warm and friendly atmosphere but also one in which it is okay to "fail" (Mills, SMEC Educational Conversation, 2010). In other words, students should be made to feel free to take risks by trying things and not be afraid of failing in pursuit of the required result. Constructivist theory (Bruner, 1966) stipulates that the role of the teacher is only as a facilitator for the development of student knowledge and not the source and giver of knowledge. The teacher is there to make sure the classroom environment is one which supports effective learning. Three elements of this dimension were implemented in this project. Academic engagement, which requires the students to show interest in the given task, show enthusiasm by taking initiative to answer questions and raise their own questions, and to help their peers. Student control requires the tasks to be student centred; they need to see it as their own project not one imposed by the teacher. Student support in which the student feels it's okay to make mistakes with no put-downs from the teacher or other students.

Recognition of Difference: Students should be made to feel their work is valued, their differences in terms of opinions, social backgrounds, etc., are seen as strengths rather than weakness. This dimension has strong connections with the concept of "recognition" justice (Fraser, 1995), as it calls for teachers acceptance of the students background not as deficit but as a strength to draw upon. One element of this dimension was implemented here. Citizenship calls for allowing students to develop skills and dispositions to be able to utilise their knowledge, and act on their social environment rather than being mere passive participants.

3. The Project

Context of the Research

At the time of this study, the PN course prepared young Emiratis at their Higher Colleges of Technology (HCT) for their Diploma Courses. In this context, PN is an aggregate of mathematical skills necessary to cope with the demands of the higher levels of diploma programs. The PN course offered within the Diploma Foundation (DF) departments across all seventeen Higher Colleges of Technology colleges in the United Arab Emirates (UAE) falls within the category of developmental education as described by Boylan, Bonham, and White (1999). Developmental education is a service provided to students who are not prepared for the academic demands of higher education (Breneman & Haarlow, 1998). Upon passing the DF, students can commence their Diploma courses. In other words, DF students are perceived, by the system, as mathematically weak, and the course aims to develop rather basic numeracy skills in order to prepare students for higher studies. The research presented in this paper focused on 3 content areas within the course, namely: Percentages, time calculation and graphs. Experience from previous years shows that these topics remain a particular challenge for many students

undergoing traditional teaching approach. They are also useful topics to deal with many demands of the students' daily life.

More than 50% of the students in the participating class came from outside the city of Abu Dhabi. The college provides bus services, at a subsidised rate, for students who require it. Some students are driven, or drive themselves to college. Those who drive themselves are mostly part-time working students. The college has a student parking area and a staff parking area within its premises.

Methodology

This study involved a group of 20 female participants, with ages of 16-36 years. The sample was purposefully chosen (Creswell 2005) because they were taught by the first author as teacher researcher, and, relative to other classes, the majority had a reasonable command of both written and spoken English. Triangulation (Stake, 2003) was achieved through multiple sources of data including (1) student presentations (2) participants' test results from the end of the module (3) participants' reflective questionnaires (4) focus groups, and (5) the use of researcher's own reflective journals. Grounded theory approach was used to analyse the data. In particular, the approach discussed by Strauss and Corbin (1998) was utilised to organise and interpret the raw data in this study.

Procedures

Traditionally, DF students are taught 8 modules during each academic year using mainly the Modular books and worksheets prepared by teachers for consolidation of taught concepts. At the end of each Module, all the DF students would take the same 50 minutes pen and paper examination. In this study, students were engaged in three projects. At the start of the study, students engaged in a brainstorming session, support by their teacher, to identify issues of concern to them to investigate using mathematics resulting in three projects: Time of Travel, Career Aspirations and Car Parking.

The Time of Travel group was concerned with the issue of whether the means of transport provided by the college could be improved to meet the needs of students who lived outside the city. Each student in the class recorded their travel times to and from college for a week. This data formed the basis of learning their mathematics and identifying the challenges some students faced in their travels to and from College. The Car Parking was concerned with the allocation of parking at the College to see if it was fairly distributed between staff and students. To obtain their data, they measured the dimensions of all car parks and worked out how many cars could be accommodated at any given time. The Career Aspirations group utilised mathematics as a tool to investigate needed action to increase the level of information available to students with regards to available career opportunities. They constructed a questionnaire which was completed by 7 classes out of the 9 classes in DF course.

Five hours every week for the duration of 6 weeks were devoted to working and reporting on the projects. To cover the material in the DF Mathematics Course Outline, the teacher researcher utilised the data collected by the participants to develop *mathematical enriched worksheets.* A separate sheet was developed to consider the data from each of the 3 projects. All students in the class attempted all 3 worksheets; first, individually in class and at home; then, they discussed their results within their project groups. Finally, the project group working on the topic presented their answers to the relevant *mathematical enriched worksheet* to the whole class.

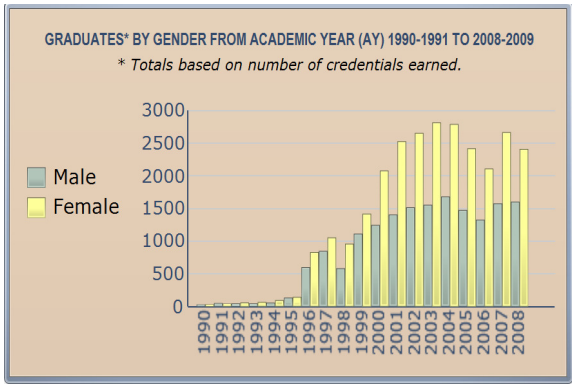
4. Results and Discussions

In this section we will reflect on the tasks adopted in this study (Hayes, Mills, Christie & Lingard, 2006) using the 7 elements of the PP framework discussed above.

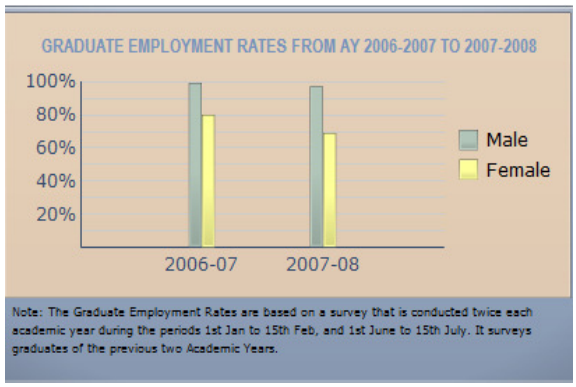
Higher Order Thinking: In another paper (Tanko & Atweh, 2012a), we demonstrated how these students have developed significant mathematical knowledge and processes that have in the past proven to be difficult in this subject. Here we will consider some evidence that these projects have allowed for the development of high order thinking with these students.

Two features of the pedagogy applied in this study were that the projects in which the students were engaged to develop their mathematics learning were chosen by the students themselves and that they were open ended. The first feature implied that the tasks were meaningful and of interest to the students. The second implied that they had to make decisions on what data was needed and what mathematics was appropriate to develop their conclusions. By themselves, these features demand higher order thinking than traditional tasks that provide students with all the data necessary for the problem solving and where the mathematical processes have been explicitly taught in the lesson. Similarly, the mathematical enriched worksheets used were based on real data from the students' research or directly related to them - hence also provided meaningful contexts for the students - and contained many open ended tasks - hence encouraged students deep thinking about the information.

For example, in the worksheet on reading graphs, 2 graphs were provided to the students published by the College as part of its *Focus of the Week* publications. One of the graphs shows the number of male and female students who have graduated from HCT from the year 1990 through 2008. The other graph shows how many graduates of HCT gained employment between the year 2006 and 2008. The open ended question on the mathematical enriched worksheet was: *Use mathematics as a tool to analyse these two graphs.*



Graph 1



Graph 2

Working individually, the students planned what kind of data to concentrate on and what kind of mathematics was needed to analyse the graphs. For example, Ayesha (*all names are pseudonyms*) noted:

> *To analyse the graph, I plan to look to see any similar thing in them. Then I will do calculations using math.*
>
> *Graph 1 (2007 to 2008):*
>
> *Male: Change = 1570-1500=70*
>
> *Percentage change = 70÷1500×100=4.67% , 2dp. Is increase*
>
> *Female: Change = 2675 – 2325 = 350*
>
> *Percentage change = 350÷2675×100=13.08%, 2 dp. Is decrease*
>
> *The 2 calculation show me that the number of male graduate is increasing at 4.67% rate, but the women are decreasing at 13.08% rate. If this continue like this then more men will graduate than women and we reach a time when very small number of women will go college. But this data is only for two years so we cannot use it to say the future will be like this or no, we need more information to reach a conclusion.*
>
> *Graph 2 (2007 to 2008):*
>
> *Male - Percentage change = 100- 97 = 3%, decrease. This only approximate because I cannot read accurately the graph*
>
> *Female - Percentage change = 80-70 =10%, decrease.*
>
> *Here I can see the percentage decrease is more for women. This mean less women graduated and instead for them to get jobs, more of them are now with no jobs, why. This is not fair for justice. Since less women finish college, they should get job, so that other women will go to college also. This will encourage more women to go college.*

Ayesha analysed and synthesised the 2 graphs and reached the conclusions that if more women gained employment after completing their college education, it may encourage more women to go to college. Ayesha has combined her calculations and her "funds of knowledge" to interpret her calculations and to arrive at some conclusion. Many made-up graphs on artificial data which appears in many textbooks or classroom working sheets are meaningless for students and may not encourage deep engagement and critical reading by the students.

Similarly, while usually students in mathematics operate on numbers without meaning and are satisfied with any resulting answer to the problem, there was evidence that the participants in this study have critically reflected on the mathematics and what it means in the context of the problem. For example, the students found out that for many of the students who use the college bus, travel by public transport would actually be cheaper. However, the students realized that decisions on which means of transport to take is not only based on mathematics. For example, Mouza uses the college bus to travel to and from school. Based on her calculations, she spends a total of 5.6 hours on the bus per week. Below are Mouza's calculations and interpretations.

2 hrs = Dh30

5.6 hrs = x

x = (30 × 5.6) ÷2 = Dh84

It will cost me Dh84 in one week to travel on public bus. We have 20 weeks in semester two, so it will cost me for the semester 84×20 = Dh1680. Now I pay Dh1900 for [the college Bus] one semester. So, is cheap to travel by public bus. But I like to use the college [bus] because I make new friends and is safe because all [of us are] students.

Similarly, Salama, who spends 827 minutes on the bus per week, preformed similar calculations and concluded:

120n = 30×827

x = (15×827) ÷120 = Dh 206.75

We have 20 weeks in one semester = 20×206.75 = 4135.00

It cost me Dh4135.00 to travel to college with public bus in one semester. I only pay Dh1900 for college bus. The college bus is cheaper. I like the college bus because my parents don't worry to bring me to college, I enter the bus. The bus picks me from front of my house, my parents see me enter the bus is important here in UAE.

These students have clearly reflected on the mathematical results from their calculations critically using their real social context (their "funds of knowledge") to interpret their calculations and arrive at some conclusion.

Substantive Conversation: The pedagogy used in this study also included a presentation by the students on their projects to the whole class. Each group had 20 minutes to make their presentations followed by 10 minutes for questioning. At the end of each presentation, the group leaders handed in a copy of their presentations to the teacher researcher. Analysis of presentations and following discussions, as well as discussions at the focus groups with the students, suggest that the students have engaged in substantive conversations on the mathematics they have done and their findings. For example: The teacher researcher recorded in his reflective journal his discussions with the Car Parking group, during which he asked them to explain how they arrived at the ratio of car parking area to number of students as 1:2. Ayesha said, "The ratio of 214 to 300 is the ratio 1:2". He asked why and she replied, "It is actually 1:1.4 but we rounded up to make sure there will be no student without space to park her car". In the focus group she added, "because rounding up will lead to more cars than there is space for. Is better to have free space than have car with nowhere to park". He asked again, if the answer was, say 214.72, would they still round down? She said, "Yes". From these examples it is reasonable to assume that the interactions have resulted in coherent shared understanding of ratio and sensible rounding. These are clear example of "talking to learn and understand" (Hayes et. al., 2006, p. 44).

The Career Aspiration *mathematical enriched worksheet* included the following question: *Calculate the percentage for each response on the summarized questionnaire. Round your answer to the nearest whole number.* Discussing the students work has allowed another substantive conversation to arise. For example, when the the teacher asked Shamsa, to explain her thinking behind the calculation,

I always think about it = 145÷81×100 = 179%

Shamsa said " I divided the total by 81 and multiply by 100". She added "I don't think my answer is correct". Why? He asked. She replied, "179 is big number, my number should not pass [more] 100". He then asked Shamsa to check what the answer would be if she divided the 81 by 145 and multiplied the answer by 100. She said, "the answer is less than 100". What is the number? He asked again. She replied, "it is 55.86%". His discussion with Shamsa has helped her to understanding how to calculate the percentage of a quantity. This is another example of "talking to learn and understand" (Hayes et. al., 2006, p. 44). Here we argue that the meanfigulness of the tasks to the real world of the students have given them confidence to engage in elaborated discussion in defending and reflecting on the reasonablness of their answers.

Connectedness to the World: All of the projects in this study were selected by the participants themselves after brainstorming sessions. All the topics were of personal importance to the participants For example: the groups that worked on the Time of Travel project consisted of all students from outside Abu Dhabi city, except one, who were directly affected by the needed time and costs of travel to and from the College; the group that worked on the Career Aspirations project consisted of students who are employed and study full time and hence were interested in questions related to career opportunities; and, the group that worked on the Car Park Parking project consists of students who drive themselves to college, thus are directly affected by available parking space. However, vested personal interest was not the only motivation. On the reflective questionnaire at the conclusion of the study, the participants were asked "Are the project(s) you have just completed the same or similar in form

with the ones you may have done in the past? Explain your answer." Some of the responses were: "All of them are about making our future better" (Muneera). "We are working to solve our problem" (Zainab). "This project is all about our life and this is different from before. Before they give us the number to use but now we use our numbers" (Rahma).

During the focus group interview with the Career Aspiration group, the teacher researcher asked the group to tell him what they liked or did not like about this method of teaching mathematics. Muneera said, "it is interesting". She added,

> *Because, if you bring (like) real issue you are making us involved in our society not just books, you will be more interested in finding the answer. You want to find the answer, like; I want to find the percentage because I want to understand the case more, because is from my side from my country or from the same girls as me. I think it will help definitely it will help [to teach mathematics this way].*

Muneera, Zainab and Rahma have indicated that their project is different from any project they might have done in the past because this one is connected to their lived lives – they were working to solve their own problem not one imposed by the teacher. In all the examples discussed, data analysis suggests that the participants have applied themselves more than what they were used to in mathematics classes because their project had real life meaning to them, and in the process they have achieved significant understanding of their PN course. This claim is in line with Mills et al's., (2009) suggestion that if the work given to students is connected to their worlds, a learning environment will be created in which they are most likely to demonstrate high levels of intellectual outcomes.

Academic Engagement: As stated earlier, DF students are perceived as mathematically weak. The first academic engagement occurred during brainstorming sessions on possible project topics and the subsequent justification by each group on what mathematics was required to successfully complete their projects. By suggesting topics and reaching agreement on which ones to pursue we argue that the participants have demonstrated the ability to show agency and contribute to group work. During class time, the teacher researcher recorded in his reflective journal the responses by participants when he asked them about their mathematics class. For example, Yasmeen said most of the time she never felt she was in a mathematics class because everyone was happily engaged. Naema said she understood mathematics in a relaxed way and as a result she had worked to the best of her ability to complete all set work. Noura said she liked to learn mathematics now because it made sense to her and she is no longer afraid of it. It is pertinent to mention here that the participants' responses on reflective questionnaires suggest this was not the case before their projects. For example, Bedour wrote "I don't like math before [this project] but now I go to class early - no late gain". Afra said "I don't like to leave my math class again [anymore] because we do fun stuff…, we are busy talking about our work, and arguing about what is right or wrong". Based on these examples, it is reasonable to argue that the students choice of real world problems that are meaningful to them has engaged them academically in the developing their mathematical knowledge.

Student Control: Right from the outset all the projects in this research were student centered, and the participants saw them as their own projects not ones imposed on them. This was achieved by ensuring that the entire project groups had team leaders to coordinate group discussions, a recorder to record the work completed, and every group member knew they would play their part during class presentations. The teacher played the role of an adviser and a facilitator. For the majority of the participants in this research, this was the first time they ever had some say in their learning process. For example, Muneera said this was the first time she ever team led a group and doing so had provided her with an unforgettable experience. She added that the projects were enjoyable because the students controlled what went on in the class. Ayesha said that although she has been a class leader during her secondary education, her experience as a leader on this project was different because the students were in charge of what to do and how to go about doing it. She added that they had gained valuable experience for their life after college.

Student Support: Care was given in this study to develop a warm, friendly atmosphere in the classroom in which it was okay to make mistakes, and no putdowns. The students felt they were free to take risks by trying things and without the fear of failure in pursuit of the required result. For example, during group presentations every group member had to play a role by presenting some part of the work to the class. The teacher researcher noted in his journal that Warda, who was a very quiet and shy member of the Car Parking group, was the one who presented on how to calculate the area of a triangle. Although she struggled to articulate her explanation of the formula, she persevered with a smile on her face and eventually her message got through. After the presentation Warda went to the teacher and said "I [am] happy I try to explain without fear". Similarly, there were instances in which participants were still relying on the teacher for directions on what to do. However, as he provided them with the necessary scaffolding without interfering too much with their decision making, the participants gained

confidence and took control of their learning. This claim was supported by Zainab as indicated on her reflective questionnaire when she wrote,

> *From the beginning I find this way [of learning] difficult, because you have to think everything by yourself. But, I try my best to think and also Goma help us sometimes. Then I become confidence. Now I like this way of learning math.*

Data analysis suggests such student support have resulted in significant increase in the participants' confidence and ability in their mathematics course.

Citizenship: At least to us, one of the most interesting outcomes in this study is that not only students were engaged academically in the tasks or that they developed significant mathematics, but they also have developed a sense of agency and the ability to use mathematics as a tool to justify the actions taken by them with the aim of improving the wellbeing of their college. Using Gutstein (2006) terminology, the students not only were able to read the world, but write the world with mathematics (Gutstein, 2006). In another paper, we have addressed the participants learning about the world (Tanko & Atweh, 2012b). Here we will discuss actions taken my students to affect their community. It is pertinent to mention here that the teacher researcher took the responsibility to support the students to develop such outcomes. Discussion with the participants considered a range of options the students can take in order to make tangible use of their findings.

At the conclusion of the Car Parking project, the participants decided that it was important that the college Director was made aware of their findings. The team leader sent him an e-mail, requesting a meeting and he accepted to have the meeting with them. During the meeting they presented their findings to him, and made recommendations for change. As a result of their action, the student car parking area was increased. Similarly, for the Time of Travel project participants took action by sending a letter, to the Student Services Coordinator at the time. In the letter they made recommendations on ways to improve the bus services at the college. As a result of their project, the starting time is now 08:30, not 07:30 as in previous academic years. This is significant because traveling into the city in the morning can be time consuming due to the volume of traffic on the road. This change would allow the students extra time to reach the college in time for the start of classes. The Career Aspiration project students took action by writing a letter, to the College Career Coordinator explaining their findings and making recommendations. As a result of their project, Career Fair shows at ADWC now include information on part-time jobs.

5. Conclusion

Although there is still more to be done in terms of exploring the effectiveness of PP as a framework for improving students' outcome, especially in different context (cultures) other than those of the Western world, data analysis from this study suggests that the principles of PP are relevant and applicable in the Middle Eastern context. We argue that, utilising PP as a framework, in this context, has allowed us to reflect on the pedagogy used in the project and have assisted in documenting students outcomes from the project. In this capacity, this paper has added to the literature in relation to the role of the PP as a framework for enhancing students' academic outcomes.

Finally, we note that one limitation of this research could be that the experimental conditions created during the research had introduced a change in routine that might have inspired and engaged the participants. There is always a danger if such approach becomes routinized then it may not be effective in the long run. This calls for further more long term research. Likewise, only 7 of the elements of the PP framework have been considered here. There is a room for research on the implementation of other dimensions of PP toward greater student outcomes.

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