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Original Paper

The Efficacy of the Concept-Rich Instruction with University Pre-Service Teachers in a Tanzanian Context Using Vygotskian Perspective

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Abstract

This paper presents the findings of a pilot study on concept-rich instruction with university pre-service teachers in a Tanzanian context. The concept-rich instruction is an instructional approach which is used to develop students' understanding of a mathematical concept (Ben-Hur, 2006). I conducted a pilot study to determine the efficacy of the concept-rich instruction to university pre-service teachers in Tanzania using Vygotskian perspective. I used a reflective journal and pre-test questionnaire to collect data while implementing the CRI in a daylong research meeting. After the pilot study, it was found that the concept-rich instruction helped preservice teachers to develop their understanding of a concept taught at schools in different ways, including defining a concept in multiple ways and relating a concept with local materials available in their daily environment. The findings have implications in the teaching and learning of the mathematical concepts that are taught at schools to the university pre-service teachers.

Keywords

concept-rich instruction, pre-service teachers, mathematical concepts for teaching, Vygotskian perspective

1. Introduction

I conducted a pilot case study with nine Pre-Service Teachers (PSTs) at one of the public universities in Tanzania in October 2016 to determine the efficacy of the Concept-Rich Instruction (CRI) in a Tanzanian context. CRI is a model of teaching which actively engages learners with a mathematical

concept in the class (Ben-Hur, 2006). The model was used to encourage PSTs' participation in learning of a mathematical concept—*pi* through small group and class discussions to develop their understanding of a concept, because participatory approach was rarely practiced in their university mathematics class.

The reason of using *pi* as an example to engage PSTs with a concept through CRI is that *pi* is a concept which is taught in Tanzanian primary and secondary schools. But, a concept is not taught to the PSTs in their university mathematics class, because the university lecturers make assumption that PSTs studied a concept while they were in schools. As the result, they leave no chance for PSTs to explore a concept in their university mathematics class.

Vygotsky's (1978) Sociocultural Theory was used in a research meeting to encourage participation in learning by allowing social interactions to take place among PSTs in small groups while learning a concept. The reason is that I believe social interaction plays a major role in learners' acquisition and understanding of knowledge while collaborating with knowledgeable others. The theory was also used in a research meeting by using local resources to engage PSTs with a concept, which were not considered as thinkable resources in teaching and learning of a concept(s) in their university mathematics class. The theory was also used to allow PSTs to reflect on their ongoing learning of a concept in a research meeting.

2. Description of Concept-Rich Instruction

CRI is a model of teaching which intends to develop learners' understanding of mathematical concepts. The model engages learners with the concepts by encouraging them to "learn and think mathematically" in small and large groups (Ben-Hur, 2006, p. vii). Despite the fact that the model is among of the instructional approaches, it is a concept-oriented because learners are encouraged to participate in learning while focusing on a concept itself (Ben-Hur, 2006).

CRI involves five components, which all contribute to the students' learning of a mathematical concept. The five components are meaning, decontextualization, recontextualization, practice and realization.

- Encapsulation conceptual understanding in words and symbols focuses to develop learners' understanding of a concept by defining it and representing the definition(s) of a concept in words and symbols.
- Decontextualization focuses on developing learners' understanding of a concept through experiencing a variety of its applications.
- Recontextualization focuses on developing learners' understanding of a concept by identifying its applications and using a concept to connect new experiences with the past experiences.
- Practice focuses on developing learners' understanding of a concept through learning by doing.
- Realization focuses on developing learners' understanding of a concept by integrating a concept into the mathematics curricula and beyond the curricula, such as in other fields and daily life situation (Ben-Hur, 2006).

The CRI model emerged when schools and mathematics teachers in the United States of America were looking for improved models of teaching that could be used to actively engage learners in learning mathematics. The major reason for looking at the alternative form of instruction was because mathematics teachers in the United States wanted to achieve first-class status in mathematics education in its schools. Ben-Hur filled the gap by developing CRI model and practicing it in mathematics classes for learners from Grades 6 to 8 in the United States. Later on, the model became popular in mathematics classes with learners in the larger North American context due to its potential to develop learners' understanding of mathematical concepts and facilitate learning achievements (Ben-Hur, 2006).

3. Method

3.1 Creation and Implementation of the Concept-Rich Instructional Activities

I created the concept-rich instructional activities before engaging PSTs with a mathematical concept in a daylong research meeting (see Table 1). The activities focused on meaning, decontextualization, recontextualization, realization and practice of a concept. After that, I implemented the instructional activities in a research meeting. PSTs worked on the activities in small groups followed by group presentations and class discussions. Class discussions were important to elaborate individual and group understandings of a concept through interactions with knowledgeable others. Practice related to a concept was done by PSTs in small groups while working on the activities focused on meaning, decontextualization, recontextualization, and realization of a concept. Practice related to a concept was also done by PSTs while presenting their small group activities in a research meeting.

Table 1. Concept-Rich Instructional Activities

Components of CRI	Sessions	Group Work Activities Followed by Presentations and Class Discussions
Meaning of a concept	One	What comes in your mind about *pi*? Please explain your answer(s) (Think, pair, and share). Given a circular object, what can you say about *pi*? Please explain your answer(s) (Think, pair, and share). What is π? Please explain your answer(s) (Think, pair, and share).
Decontextualization of a concept	Two	What is the value of pi? Please explain your answers (Think, pair, and share). What are the strategies for finding the value of *pi?* (Think, pair, and share). How can you find the value of *pi* using local materials/circular

		objects? (Think, pair, and share). How can you find the value of *pi* using Archimedes approach for better approximation of the value? Please explain your answers (Think, pair, and share).
Recontextualization of a concept	Three	What concepts do we need to know before and after learning *pi*? Please explain your answer(s). Think, pair, and share. What are the applications of *pi* in mathematics and other fields such as science? Please explain your answers. Think, pair, and share.
Realization of a concept	Three	Where is *pi* in our daily environment? Please explain your answer(s) Think, pair, and share. What is the importance of *pi*? Please explain your answer(s). Think, pair, and share. What are the applications of *pi* in our daily life? Please explain your answer(s). Think, pair, and share.

3.2 Concept-Rich Instructional Sessions

The instructional sessions took place on Saturday in the same boardroom in the university. The boardroom provided comfortable space and a large table around which the PSTs were able to sit comfortably and within easy access to each other.

There were three sessions in a daylong meeting. The first session started from 9:30-11:00. The second session started from 11:30-1:30. The third session started from 2:30-4:30. Each session took a duration of two hours. The three sessions were spaced for tea and lunch break. Tea break was 30 minutes while lunch break was 1 hour.

3.3 Data Collection Methods

This pilot study was used to gather data before the main investigation in another study, which focused on how CRI model revealed PSTs' expressions of their understanding of a mathematical concept. The data was collected using two methods in a daylong research meeting. The data was collected using an open-ended pre-test questionnaire before conducting a pilot study in a research meeting. Reflective journal was also used to collect data during conducting concept-rich instructional sessions. This means that reflective journal was used in session one, session two, as well as session three in two different ways. A reflection was used to gather information about individual participants' ongoing learning of a concept. A final reflection was used to gather information from the individual participants about what they learned in a research meeting focused on their understood, surprising, unfamiliar and familiar ideas about *pi.*

There were 7 items in a pre-test questionnaire, which were similar with items in the reflective journal. The items are: "what is *pi*? Please explain for me", "what is the value of *pi*? Please explain for me",

"what are the strategies for finding the value of *pi*? Please explain for me", "what concepts do we need to know before learning *pi*? Please explain for me", "what is the importance of *pi*? Please explain for me", "where is *pi* in our daily life environment? Please explain for me", and "what are the applications of *pi*? Please explain for me". However, a final reflection comprised four items: "what surprised you today about *pi* as a concept? Please explain for me", "what have you understood today that you did not understand before about *pi*? Please explain for me", "what have you not understood today about *pi* as a concept? Please explain for me", and "what was unfamiliar to you today about pi as a concept? Please explain for me".

4. Result

The efficacy of the CRI model was seen through analyzing data collected from a pre-test questionnaire and reflective journal using Ben-Hur (2006). I focused on a research question: Can CRI model work to Tanzanian university PSTs for development of their understanding of a mathematical concept through participating in a research meeting? I compared the individual responses in a pre-test questionnaire with that of a reflective journal in each item to create categories. I was able to determine the efficacy of the CRI model to the university PSTs in the Tanzanian context. The efficacy of the CRI was observed in a variety of ways, including the following mathematical ideas in the subsections below.

4.1 Meaning of a Concept

CRI helped PSTs to develop multiple ways of defining *pi*. PSTs defined a concept in different ways, including *pi* as a ratio of two parameters (circumference and diameter) of a circle, *pi* as ratio of two measures (circumference and diameter) of a circular object, and *pi* as the number of diameters required to complete the circumference of the circle or circular object. The responses about the meaning of *pi* are as described in Table 2 below.

Table 2. Meanings of Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
Pi is the ratio of circumference of circular object to its diameter	-	2
Pi is the ratio of circumference of a circle to its diameter	1	6
Pi is the number of diameters required to complete the circumference of a circle/circular object	-	3

From the Table above, the number of responses in bothered-test questionnaire and reflection and the number of PSTs of the pilot study are not the same. I learned that in a pre-test questionnaire, about 89

percent of the PSTs were not aware to give the definition of *pi,* which is defined as the ratio of circumference of a circle/circular object to its diameter. But after attending the pilot study sessions all PSTs became aware to define *pi* in multiple ways. Also, for justification, 11 percent of the PSTs in a pre-test questionnaire was able to justify the meaning of *pi* by writing, "for any circumference of a circle dividing by its diameter, a constant number will be acquired which is approximated equivalent to 3.14".

CRI helped PSTs to develop multiple ways of the meaning of the value of *pi.* PSTs provided the meaning of the values of *pi* in the class in a variety of ways, including the value of *pi* is approximated equivalent to 3.14 for easy mathematical computations, the value of *pi* is an irrational number which goes to infinity (3.14…), and the value of *pi* is represented by the symbol π for accurate mathematical computations. The PSTs' responses of the meaning of the value of *pi* are as described in Table 3 below.

Table 3. The Value of Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
It is approximated to 3.14 for easy computation and memorization	1	9
It is irrational number (3.14…)	-	3
It's symbol, π for accurate mathematical computations	-	2

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of PSTs of the pilot study are not the same. Before conducting the session, about 11 percent of the PSTs was able to give the correct value of *pi* as approximated to 3.14. The remaining about 89 percent of the PSTs responded to this item by writing the value of *pi* as 3.14 or $\frac{22}{7}$. Among these 89 percent of the PSTs responded in a pre-test questionnaire by arguing that the value of *pi* is $\frac{22}{7}$ whereby when taking 22 and divide by 7 the answer is approximated to 3.14. However, after conducting the pilot study, all PSTs responded correctly for the value of *pi* as approximated equivalent to 3.14. As such, I learned that, there were misconceptions of the value of *pi* among participants before attending this pilot study.

4.2 Decontextualization of a Concept

CRI helped PSTs to develop multiple ways of finding the value of *pi.* PSTs provided multiple strategies of finding the values of *pi* in the class in a variety of ways, including the value of *pi* can be obtained by: taking the ratio of two parameters (circumference and diameter) of a circle, taking the ratio of two measures (circumference and diameter) of a circular object, and counting the number of diameters that

goes around the circumference of a circle or circular object. From these three strategies identified, the first two strategies were identified before conducting the sessions, and the third strategy was identified by the PSTs after attending the pilot study sessions as we can see in Table 4 below.

Table 4. Strategies for Finding the Value of Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
By taking the ratio of the circumference of a circle to its diameter	1	7
By measuring the circumference and diameter of a circular object, thereafter take the ratio of the two measures (circumference of the circular object to its diameter) to obtain the value of *pi*	1	5
By counting the number of diameters that goes around the circumference of a circular object	-	2

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of the PSTs of the pilot study are not the same. Before conducting the session, about 22 percent of the PSTs did not respond to this item in a pre-test questionnaire, and 22 percent of the PSTs were able to respond to this item correctly. But, after conducting the sessions, all PSTs were able to respond correctly to this item in a reflection. In doing so, I learned that the pilot study sessions helped PSTs to identify different strategies for finding the value of *pi* using real objects/local materials.

4.3 Realization of a Concept

CRI helped PSTs to develop their understanding of the importance of *pi*. PSTs addressed that *pi* is important in a variety of ways, including *pi* is used to find the: circumference of a circular object, area of a circular object, volume of 3D objects, and pressure of fluid flowing in a pipe. Table 5 below provides the PSTs' responses about the importance of *pi*.

Table 5. The Importance of Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
It helps us to find the circumference of the circular objects	3	6

It helps us to find the area of circular objects	4	7
It helps us to find the volume of circular objects (3D objects)	2	7
It helps us to determine the pressure of the fluid that flows in a pipe	-	1

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of the PSTs of the pilot study are not the same. Before conducting the pilot study sessions, about 11 percent of the PSTs did not respond to this item in a pre-test questionnaire, 34 percent of the PSTs did not respond correctly to this item while 55 percent of the PSTs were able to respond to this item correctly. But after conducting the pilot study sessions, all PSTs responded correctly to this item in a reflection. In doing so, I learned that the pilot study sessions were effective to help PSTs understand clearly the importance of *pi* in mathematics and other fields including physics.

CRI helped PSTs to realize that *pi* is not an abstract concept. *Pi* is connected to real things that we see. PSTs responded to both pre-test questionnaire and reflection about *pi* in their daily environment as shown in Table 6 below.

Table 6. Pi in Our Daily Environment

Category	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
Pi is found everywhere in circular objects	3	9

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of the PSTs of the pilot study are not the same. Before conducting the pilot study session, 34 percent of the PSTs were able to respond correctly to this item in a pre-test questionnaire, 11percent of the PSTs did not respond to this item and the remaining 55 percent of the PSTs responded to this item in terms of the applications of *pi*. But after conducting the pilot study sessions, all PSTs responded correctly to this item in a reflection. As such, I learned that the pilot study session was effective in helping the PSTs identify where *pi* is found in their daily environment.

4.4 Recontextualization of a Concept

CRI helped PSTs to develop many concepts needed to know before learning the concept of *pi*. PSTs provided a variety of concepts needed to know including circumference of a circular object, diameter of the circular object, meaning and shapes of circular figure, measurement, ratio, and relationship between the circumference and diameter of the circular object. From a pre-test questionnaire and reflection, the following concepts were identified as shown in Table 7.

Table 7. Concepts that Students Need to Know Before Learning Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
The circumference of circular objects	2	3
Diameters of circular objects	2	3
Meaning (shapes/structures) of circular objects	1	2
Measurement	-	7
Ratio	-	5
The relationship between the circumference and diameter of a circular object	-	1
Constant number/approximations of number	1	1

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of the PSTs of the pilot study are not the same. Before conducting the pilot study, about 11 percent of the PSTs did not respond to this item, 55 percent of the PSTs responded incorrectly to this item and 34 percent of the PSTs responded correctly to this item. But after conducting the pilot study sessions, all PSTs responded correctly to this item in a reflection by mentioning many concepts compared to the concepts that were mentioned in a pre-test questionnaire. As such, I learned that, after conducting the pilot study sessions, PSTs were able to identify more concepts that we need to know before learning the concept of *pi* as we can see in the table above.

CRI helped PSTs to develop a variety of ways of the applications of *pi*. PSTs were aware about the applications of *pi,* including a concept is used to find the: circumference of a circular object, area of a circular object, volume of a circular object, modulus of a circular object and pressure of a fluid flowing in a pipe. Table 8 below gives the PSTs' responses about the applications of *pi*.

Table 8. The Applications of Pi

Categories	Number of Responses in a Pre-Test Questionnaire	Number of Responses in a Reflection
It is used to find the circumference of a circular object	4	5
It is used to find the area of a circular object	6	9
It is used to find the volume of a circular object	2	8
It is used to find the modulus of a circular object	-	1
It is used to find the pressure of a fluid that flows in a pipe	-	3

From the Table above, the number of responses in both pre-test questionnaire and reflection and the number of the PSTs of the pilot study are not the same. Before conducting the pilot study session, about 22 percent of the PSTs did not respond to this item, 11 percent of the PSTs responded incorrectly to this item and 64 percent of the PSTs responded to this item in a pre-test questionnaire. But, after conducting the pilot study, all PSTs responded correctly to this item in a reflection by mentioning many applications of *pi* compared to the number of responses in a pre-test questionnaire. As such, I learned that the pilot study sessions were effective in helping the PSTs to identify many applications of *pi*.

CRI helped PSTs to realize a lot of ideas about *pi* in the pilot study. PSTs' surprises existed in the daylong meeting focused on *pi* using CRI model in a final reflection. These surprises include the concept of *pi* is wide, important, not abstract, and applicable. Individual PSTs raised issues that surprised them after attending the pilot study sessions as we can see in Table 9 below.

Table 9. Surprising Ideas about Pi

Categories	Number of Responses in a Final Reflection
The concept of *pi* is very wide than what I knew before attending this session	1
The importance of *pi*	1
Pi is not an abstract idea; it is a concept where by its value is obtained by taking the ratio of circumference of a circle to its diameter.	5
Applications of *pi* and its value	1
The more the decimal places in the approximations of the value of *pi*, the more the accurate is the answer	1
The value of *pi* is approximated to 3.14 and it is not equal to 3.14	2
The value of *pi* is an irrational number (3.14…)	3
The value of *pi* equals to is not valid since there is no apparatus/ tools which can be used to verify this value	1
About 3.14 times the diameter equals to the circumference of a circular object	2

From the Table above, the number of responses in a final reflection and the number of the PSTs of the pilot study are not the same. From these teachers, I have learned that, the PSTs were having a narrow understanding of the concept of *pi* before attending to this pilot study due to a lot of divergent responses that emerged at the end of the pilot study in a final reflection.

CRI helped PSTs to understand a variety of ideas about *pi* in the pilot study. When the PSTs were asked to respond to the item question in a final reflection, what have you understood today that you did not understand before about *pi*? Individual PSTs raised ideas of *pi* that they were not aware at the end of the pilot study sessions, including the value of *pi*: as an irrational number (3.14…), can be obtained

from the ratio of two measures (circumference and diameter) of a circular object, can be obtained using Archimedes approach for better approximation of the value, and is not equal $\frac{22}{7}$. Table 10 below provides the ideas about *pi* that the PSTs were able to understand after attending the pilot study sessions.

Table 10. Understood Ideas About Pi

Categories	Number of Responses in a Final Reflection
The value of *pi* which is irrational number	4
The value of *pi* goes to infinity (3.14…)	2
The value of *pi* is obtained by taking the ratio of the circumference of a circular object to its diameter	7
The concept of Archimedes method for approximation of the value of *pi* whereby when counting the number of diameters that goes around the circumference of a circle gives the value of *pi*	2
The value of *pi* is approximated to 3.14 and it is not equal to	3
For the accurate computations, we better use the symbol for *pi* which is to represent its value in (mathematical) computations	1

From the Table above, the number of responses in a final reflection and the number of the PSTs of the pilot study are not the same. From this item, I have learned that before attending the pilot study sessions, PSTs thought that *pi* is 3.14 or $\frac{22}{7}$ only, But after attending this pilot study, they realized a lot of ideas that they were not aware with *pi* as a concept due to a lot of divergent responses that emerged at the end of the pilot study in a final reflection as we can see in the Table above.

Finally, CRI helped PSTs to realize unfamiliar ideas before attending pilot study sessions. These unfamiliar ideas include using Archimedes approach to better approximate the value of *pi*, the value of *pi* is not a fraction ($\frac{22}{7}$), and the value of *pi* can be obtained by taking the ratio of two measures (circumference and diameter) of a circular object. About 89 percent of the PSTs raised ideas of *pi* that they were not familiar with them before attending the pilot study sessions as we can see in Table 11 below. However, 11 percent of the PSTs did not respond to this item in a final reflection.

Table 11. Unfamiliar Ideas about Pi

Categories	Number of Responses in a Final Reflection
i. Archimedes method: the value of *pi* which is approximated to 3.14 is equal to about 3.14 of the number of diameters to complete the circumference of a circular	2

object.	
ii. The value of *pi* is not a fraction	2
iii. The more you use the value of *pi* with many decimal places, the more you get the accurate answer in the computations. Therefore, it is better to use the symbol of *pi* (π) in the computations involving the use of *pi* instead of using the approximated value of *pi* to two decimal places ($\pi \cong$	1
iv. Irrationality of *pi*	1
v. The value of *pi* is approximated equivalent to 3.14 and it is not equal to	1
vi. The value of *pi* is obtained by taking the ratio of circumference of a circular object to its diameter.	1

From the Table above, the number of responses in a final reflection and the number of the PSTs of the pilot study are not the same. From these responses among the PSTs, it seems that the PSTs were not aware with a lot of ideas about *pi* before attending this pilot study. Therefore, from the Table above, I learned a lot of unfamiliar issues about *pi* from the PSTs, including the following ways. PSTs were not aware that: *pi* is a concept which is defined as the ratio of circumference of a circle to its diameters; Archimedes method for approximation of the value of *pi*; the number of diameters required to complete the circumference of a circle is about 3.14 which represents the value of *pi*; and the value of *pi* is an irrational number (3.14…).

5. Validity and Reliability of the Study

The validity of this study was ensured (Creswell, 2014) in the following ways. The first way involved verification and confirmations of the participants' responses. The individual PSTs reviewed their responses for trustworthiness and accuracy and to confirm the dependability of data obtained through a pre-test questionnaire and reflective journal after a research meeting. PSTs were asked to clarify responses, when necessary.

The reliability of this study was ensured based (Creswell, 2014) while focusing on the conducted pilot study and data collection techniques. The findings from the pilot study confirmed that the concept-rich instructional processes were effective, because each participant was asked at the end of the instructional meeting to reflect on the whole day lesson. The recommendations from my pilot study participants ensured the soundness of the created instructional activities.

6. Discussion

This paper has described the efficacy of the CRI in the Tanzanian context. PSTs were engaged with the concept of *pi* through CRI model in the pilot study. In doing so, CRI helped PSTs to develop their understanding of *pi*, such as realizing different ways of defining a concept and multiple ways of finding the value of *pi* using circular objects. As such, this model is potential to develop PSTs' understanding of

the mathematical concepts related to their work of teaching.

Vygotskian perspective also played a conducive learning environment to the university PSTs in a research meeting. First, using local resources in a research meeting was important to develop PSTs understanding of *pi*. As a result, I propose to use local resources as teaching and learning resources in university mathematics class to help PSTs relate local materials in their academic settings. Also, PSTs might use local resources in their own mathematics classrooms after completion of their university degree program. Second, social interactions among PSTs through collaboration with knowledgeable others in small and class discussions helped to encourage PSTs' participations in learning. Finally, allowing PSTs to reflect on their ongoing learning of a mathematical concept helped individual PSTs to realize what they learned and surprising ideas about *pi*.

7. Concluding Thoughts

From the findings of a pilot study, it shows that CRI model was potential for PSTs' conceptual understanding and development in a research meeting. PSTs developed multiple ways of defining *pi* and finding its value. PSTs also deepened their understanding of the applications of *pi* in mathematics and other fields such as life practice. These show that CRI model can be used to develop University PSTs' understanding of mathematical concepts in Tanzania and encourage individual PSTs' participations in learning of the concepts.

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