Investigating Worked Example as an Effective Instructional Strategy in Mathematics Classrooms in Papua New Guinea

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What did I do?

- Experimented if Worked Example instructional strategy can be effective to teach mathematics in PNG as advocated substantial empirical studies (Sweller, Ayres, & Kalyuga, 2011; Pass, Renkl & Sweller, 2003)

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Why Worked Example?

Cognitive Load Theory argues that Instructional material if aligned with learners cognitive architecture is effective.

- Worked Example, a Cognitive Load Effect is effective for novice learners as it emphasizes on less mental effort and acquisition time in learning (van Gog et al, 2004).

Human Cognitive Architecture- the way humans learn, think & solve problem

- Long-term Memory (Unlimited Space)
- Working Memory (Limited Space)

Conventional Instructional strategy (Explicit Instruction or Direct Teaching)

Algebraic expressions can be written using pronumerals. Writing algebraic expressions is to write expressions using pronumeral matching different situation.

An algebraic expression is a collection of algebraic terms. For example, 2a, or $7m + 3n - 5$ or $6ab - b^2 + 4$ are al expressions.

Example

Write an algebraic expression of the following using x for pronumeral 1, y for pronumeral 2, and z for pronumeral 3.

c. Six times pronumeral 1 plus four times pronumeral2
d. Eight multiply by pronumeral 1 plus five multiply pronumeral 2 plus three times pronumeral 3.
e. The product of one and pronumeral 1 is multiplied by two plus the product of two and pronumeral 1 is multiplied by three plus the product of four and pronumeral 1 is multiplied by two.
f. When the product of five and pronumeral 2 is added to twelve, the result is twenty-two.

Answer

a.

$6 \times x + 4 \times y$

$\rightarrow 6x + 4y$

$8 \times x + 5 \times y + 1 \times z$

$\rightarrow 8x + 5y + z$

b.

$2 \times (1 \times x) + 3 \times (2 \times x) + 2 \times (4 \times 1)$

$\rightarrow 2(x) + 3(2x) + 2(4x)$

$\rightarrow 2x + 6x + 6x$

c.

$\rightarrow 5 \times y + 12 = 22$

$\rightarrow 5y + 12 = 22$

Worked Example Instructional Strategy

Worked Example 1B

Eight multiply by pronumeral 1 plus five multiply pronumeral 2 plus three times pronumeral 3.

Answer

$\rightarrow 8 \times x + 5 \times y + 1 \times z$

$\rightarrow 8x + 5y + z$

a. Four multiply by pronumeral 1 plus three multiply by pronumeral 2 plus one times pronumeral 3.

b. Five multiply by pronumeral 1 plus five multiply by pronumeral 2 plus one times pronumeral 3.

Non-routine Problem Solving Based

Non-routine problem solving - Lesson 1

Topic: Writing Algebraic Expressions and Equations
Use the resources given to you in each of the containers to write Algebraic Expressions.

1) Write an algebraic expression, using pronumerals, for the Counter container. (Note: use only the first letter of the colour or object in your expressions for the pronumerals, e.g., Yellow = ***y***, blue = ***b***, red = ***r***, green = ***g***, crocodile = ***c***, grape=***g***, shark=***s***; etc.). Use only the first letter of the colours or objects as the pronumeral.
   a) For the container 1A1, express in algebra:
      i) Number of Yellow plus number of Green objects

      ii) Number of Red plus Number Blue objects

   b) For the container 1A2, express in algebra
      i) Number of Kangaroos plus Number of Crocodiles minus number of sharks

      ii) Number of Grapes minus Number of Oranges plus Number of Apples

2) Write an algebraic expression for the Joggle Eyes in the containers according to their sizes. If the smallest Joggle eye is *x*, the next to size x will be *2 times x*, and the size after this will be *3 times x*, and so on. Write the expression for:
   a) Container 1B1

   b) Container 1B2

3) Write in algebraic equivalent expressions using the beads according to their colours to express the following situation:

   a) Container 1C1 plus ten equals to Forty.

   b) Container 1C2 plus Eleven equals to Fifty-nine.

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Hypothesis

Research Question

To what extent will the learning gains of the students who were taught through worked example teaching strategy differ from the students who were taught through non-routine problem solving and conventional teaching strategies?

Hypothesis

Worked Example-based teaching strategy would lead to higher learning gains than the non-routine problem solving and conventional teaching strategies.

How was it done?

Methodology

Methodology: Quasi-experimental

Pre-test

- Attitudinal Survey

Intervention

- Worked Example Worksheet
- Cognitive Load Survey on worksheet

Post-test

- Attitudinal Survey
- Test
- Cognitive Load Survey on test

Sample (Cohort based Randomization)

Group	Number of Students	M	F
Worked Example Based (Group A)	60	28	32
Non-routine Problem Solving (Group B)	59	31	28
Conventional Learning (Group C)	55	27	28
Total	**174**	**86**	**88**

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Results on Test (ANOVA using SPSS)

Group Mean (Standard Deviation) on Test		
Teaching Strategy	**Similar**	**Transfer**
Worked Example Based	1.26 (0.46)	1.05 (1.05)
Non-routine Problem Based	0.71 (0.42)	0.75 (0.95)
Conventional Based	1.06 (0.45)	1.01 (0.93)

Results- Test

- For the similar test scores, the univariate test revealed significant group differences $F(2, 151) = 19.64$, $MSe = 3.88$, $p = .000$ *partial* $\eta 2 = 0.206$ where the worked example teaching strategy group outperformed the non-routine problem based group under a Turkey B post-hoc test.
- The univariate test also revealed significant group difference at $p < .10$ level, $F(2, 151) = 19.64$, $MSe = 19.64$, $p = .082$ *partial* $\eta 2 = 0.206$ where the worked example strategy group outperformed the conventional group.
- Univariate tests of the transfer revealed no significant difference.

Results Cognitive Load Survey (MANOVA SPSS)

Group Mean (Standard Deviation)							
Teaching Strategy	**Mental Effort Invested in Lesson**	**Mental Effort Invested in Problems**	**Concentration level**	**Motivation level**	**Understanding level**	**Problem Solving difficulty**	**Learning difficulty level**
Worked Example Based	1.70 (0.78)	1.79 (0.85)	4.39 (0.85)	4.04 (0.81	4.32 (0.83)	1.86 (0.84)	1.77 (0.89)
Non-routine Problem Based	3.77 (0.98)	3.93 (0.84)	4.12 (0.89	3.55 (1.00)	3.95 (1.02)	2.17 (0.98)	2.03 (0.90)
Conventional Based	3.94 (0.89)	4.04 (0.90)	4.17 (0.78)	3.73 (0.99)	4.36 (0.86)	1.96 (0.78)	1.89 (0.73)

Results- Cognitive Load Survey

- Because of the multiple scales used in this survey (7 scales), a MANOVA was completed. Roy's Largest Root indicated at $p < 0.05$ that there was significant difference at $F(2, 168) = 45.86$, $MSe = 1.99$, $p = .000$ partial h2 = 0.67.
- Univariate tests indicated that for the mental effort invested during the lesson, there was significant $F\ (2,166) = 110.20$, $MSe = 87.23$, $p = .000$, *partial* $\eta 2 = 0.57$; where the worked example group invested less mental effort than the non-routine problem based and the conventional group under the Turkey B post-hoc test.
- Univariate tests also indicated significant effect of the mental effort invested in the problems solved during the lesson, where $F\ (2,166) = 122.03$, $MSe = 90.45$, $p = .000$, *partial* $\eta 2 = 0.595$; where the worked example based group invested less mental effort in the problems solved.
- The univariate test again indicated a significant result in the level of understanding, $F\ (2,166) = 4.11$, $MSe = 2.95$, $p = .02$, *partial* $\eta 2 = 0.047$, where, the worked example based increased students level of understanding on the topic than the non-routine problem based and the conventional strategies.
- All other tests revealed no significant results.

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Results Attitudinal Survey (MANOVA SPSS)

Mean (Standard Deviation)				
Teaching Strategy	**Personal attitude**	**Usefulness**	**Teacher attitude**	**Instructional approach**
Worked example based	3.53 (0.53)	3.75 (0.47)	3.61 (0.44)	3.74 (0.47)
Non-routine Problem based	3.60 (0.55)	3.54 (0.45)	3.47(0.50)	3.73(0.42)
Conventional based	3.63(0.50)	3.52 (0.42)	3.37(0.44)	3.94(0.36)

Results- Attitudes toward Mathematics Survey

- A MANOVA was completed because of the multiple subscales (4 subscales), and according to Roy's Largest Root, there was significant difference at the point $p < 0.05$ level: $F(2, 168) = 5.92$, $MSe = 0.143$, $p = .00$ *partial* $\eta2 = 0.125$.
- Univariate test at $p < 0.05$ indicated that the usefulness subscale produced as significant effect at $F(2,168) = 4.29$, $MSe = 0.87$, $p = .015$ *partial* $\eta2 = 0.049$, where the worked example based strategy demonstrated higher understanding of its (mathematics) usefulness than the non-routine problem based and the conventional groups.
- There was also a significant effect for the subscale on teacher's attitudes towards students' mathematics learning: $F(2, 168) = 3.65$, $MSe = 0.78$, $p = .028$ *partial* $\eta2 = 0.042$, in which the worked example group perceived higher understanding on teachers' impact on their learning.
- Univariate test indicated a significant effect on the strategy used: $F(2, 168) = 4.48$, $MSe = 79$, $p = .013$ *partial* $\eta2 = 0.051$.
- The subscale on personal attitude revealed no significant difference.

Discussion:

Worked example Based group outperformed both the non-routine problem solving and the conventional teaching method for similar problems, however no significant difference were revealed for the transfer problem in the test .

Students in the worked example group invested significantly lower mental effort during problem solving and learning, demonstrated higher motivation and found the lessons easier to learn compared to the students in the non-routine problem based and conventional teaching method.

Worked Example-based teaching strategy would lead to higher learning gains than the conventional teaching strategies was ACCEPTED

Conclusion

- Worked Example have been found to be superior to both conventional and non-routine problem solving methods as supported by the Cognitive Load Theory.
- The Conventional and Non-routine problem solving method imposed higher cognitive loads on the working memory, whereas Worked example did not distract the learners to look for strategies or information to solve problems.
- Furthermore, learners in Worked Example group solved the problems quickly than those in the other groups.
- Using one worked example and two practice problems have benefited students in the transfer questions.

Implication on Mathematics Learning

1. English as a Second Language
2. National Curriculum Structure
3. Beliefs and Attitudes towards mathematics learning

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Thank you

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