ICSAT INTERNATIONAL PROCEEDING
ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

Analysis of Mathematical Creativity in Problem-Based Learning According to Metacognitive Knowledge

Widya Salsabila Amri[1], Sabri[2]*, Rusli[3]
[1,2,3] Mathematics Education Study Program
Universitas Negeri Makassar
[1]Email: widyasalsabilamrii@gmail.com
[2]Email: sabri@unm.ac.id
[3]Email: rusli.siman@unm.ac.id
*Corresponding author, Email: sabri@unm.ac.id

Abstract
This research aims to analyze the mathematical creativity of STKIP Andi Matappa students in problem-based learning according to metacognitive knowledge. The research type was case study. In this research, six subjects were selected based upon their metacognitive knowledge. Two students were from the declarative knowledge dominant group, two from the procedural knowledge dominant group, and two from the conditional knowledge dominant group. The instruments used are a metacognitive knowledge questionnaire, a mathematical creativity test and an interview guidance. The results of the research are as follows: 1) one subject from conditional knowledge group is able to show all indicators of creative thinking skills well, namely, fluency, flexibility, novelty and elaboration and she could be classified into level 3 (creative), whereas another subject from the same group is able to show 2 indicators, namely, fluency and elaboration and he could be classified into level 2 (creative enough); 2) two subjects each from declarative knowledge and procedural knowledge group are only able to show one indicator, namely, the elaboration and they could also be classified into level 2 (creative enough).

Keywords*: Mathematical creativity, problem-based learning, metacognitive knowledge*

INTRODUCTION

Mathematical creativity refers to students' capacity to recognize and find uncommon ideas or objects when solving mathematical problems, and it includes fluency, flexibility, originality, and elaboration. In mathematics, problems are questions that must be solved or answered to. A problem, according to the mathematics dictionary, is anything that demands a solution, a case, a question, or a question that requires an answer (Zakaria et al., 2007; Fardah, 2012).

Table 1 Indicators of Student Creativity in Solving Mathematical Problems

Indicators	Solving Mathematical Problems
Fluency	Students solve math problems with more than one answer.
Flexibility	Students solve math problems one way and then other ways.
Originality	Students solve math problems with their own ideas.
Elaboration	Students solve mathematical problems by providing details and coherently.

Based on the findings of observations and interviews with the lecturers of mathematics education study program at STKIP Andi Matappa, it was found that students still lacked space to express their creative thinking and opportunities to solve problems in ways other than those taught by the lecturers. On the other hand, students are sometimes still hesitant to develop their own thoughts and knowledge of

ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

mathematical concepts; therefore, it cannot be denied that this has limited students' creativity. Table 1 describes the indicators of creativity in solving mathematical problems based on creative thinking (Kholikoh, 2016; Ricardo et al., 2014).

In solving a problem, this is closely related to metacognitive knowledge. Metacognition is defined as the awareness of how someone learns, the ability to assess the difficulty of a problem, the ability to observe the level of understanding, the ability to use various pieces of information to achieve goals, and the ability to assess someone's learning progress (Baker & Brown, 1984). There are three types of metacognitive knowledge, namely: 1) declarative knowledge – knowledge about the self as a learner and the factors affecting his/her performance; 2) procedural knowledge – knowledge about how to perform using skills or strategies; and 3) conditional knowledge – knowledge about the condition in which the knowledge could be useful (Flavell, 1979).

This study aims to: 1) describe the mathematical creativity of students with declarative knowledge dominance in problem-based learning; 2) describe the mathematical creativity of students with procedural knowledge dominance in problem-based learning; and 3) describe the mathematical creativity of students with declarative knowledge dominance in problem-based learning.

METHOD

This study uses case study research to describe students' mathematical creative thinking skills in problem-based learning in terms of metacognitive knowledge. The data were gathered through giving test, filling out questionnaires, and conducting interviews. Due to the pandemic, the test was conducted online. The test questions were in the form of open-ended questions, with three essay items. The questionnaire was completed via WhatsApp media and an online Google Form and then each subject was interviewed about the test questions in order to collect more information

This research was conducted online for STKIP Andi Matappa students. Six subjects were selected based upon their metacognitive knowledge. Two students (S3 and S4) were from the declarative knowledge dominant group, two (S5 and S6) from the procedural knowledge dominant group, and two (S1 and S2) from the conditional knowledge dominant group.

The collected data is then qualitatively analyzed, which involved the following steps: (1) data triangulation, which aimed to obtain valid data; the method triangulation was used, which involved comparing data collected during interviews with student work; (2) reducing, abstracting, and explaining data; (3) interpreting data; and (4) concluding.

The following are the criteria for the level of creative thinking skills (Fauzi, 2019).

Table 2 Criteria Level of Creative Thinking Skills

Nilai	Criteria
$32 < n \leq 48$	Creative
$16 < n \leq 32$	Creative Enough
$n \leq 16$	Less Creative

ICSAT INTERNATIONAL PROCEEDING
ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

RESULTS AND DISCUSSION

Results

This study was carried out by giving a test, followed by questionnaires and interview tests for six subjects. Due to the pandemic, the tests were administered online. Following the result of the research, only one of the six subjects fulfilled the four indicators for creative thinking: fluency, flexibility, originality, and elaboration.

The following is a discussion of problem-based mathematical creativity abilities in terms of students' metacognitive knowledge**.**

Mathematical Creativity of the First Subject (S1)

In Figure 1, S1 presented two solutions to the problem, the first by applying the volume formula for the cube, and the second by using the volume of the quadrilateral pyramid. The problems were answered in detail, yet the solutions were still useful in other subjects. Based on the interview, she could explain the stages of the process quite well and drew conclusions about what shapes were obtained in solving the problem. Therefore, it could be concluded that in the first question, S1 was able to show indicators of fluency and elaboration, although he did not show indicators of flexibility and originality.

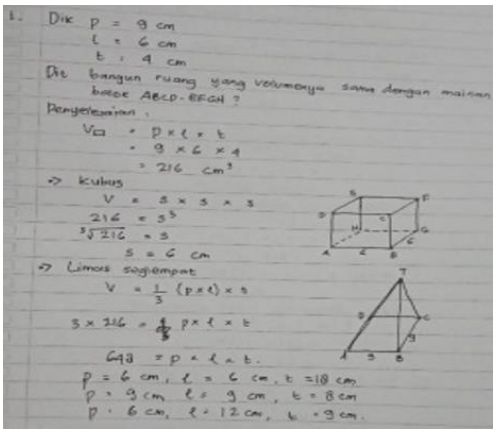


Figure 1 The Answer of the First Question (S1)

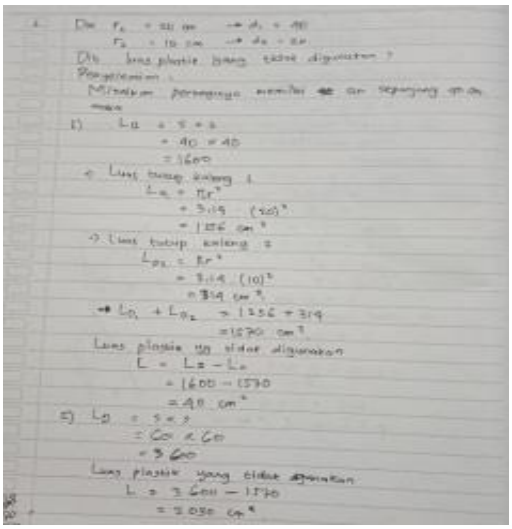


Figure 2 The Answer of the Second Question (S1)

In Figure 2, S1 can give an idea to solve the problem, namely in estimating the sides of a square on a sheet of plastic, namely in the first answer the subject estimates the length of the side of the square to be equal to the diameter of the large circle. While in the second answer, the subject estimates the length of the side of the square is equal to the sum of the diameters of the two circles. The problem is done in detail and uses a method that is not done by other subjects, namely by estimating the length of the side of the plastic that is sufficient to cover the two circles. Based on the interview, S1 can explain the stages of the process quite well. So, it can be concluded that in the second question, she was able to show indicators of fluency, novelty and elaboration, although she did not show an indicator of flexibility.

ICSAT INTERNATIONAL PROCEEDING
ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

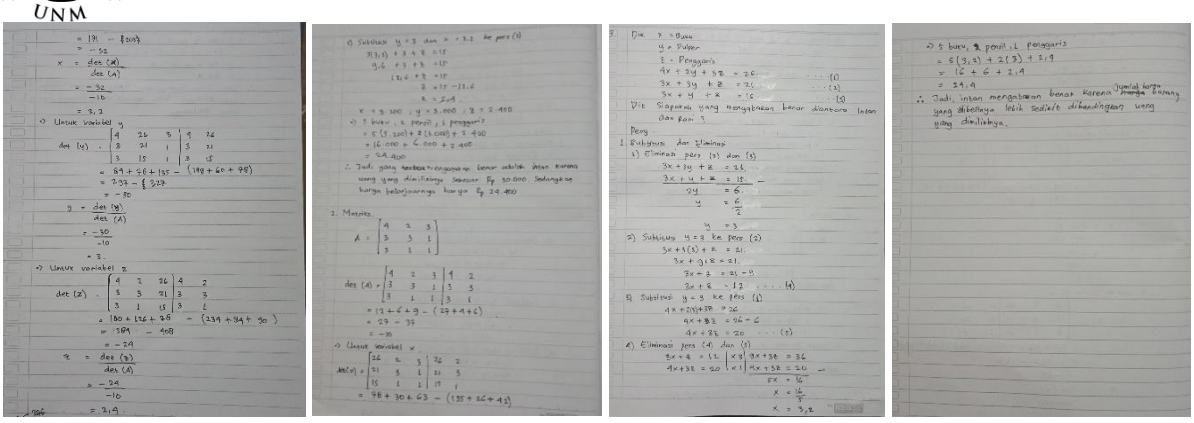
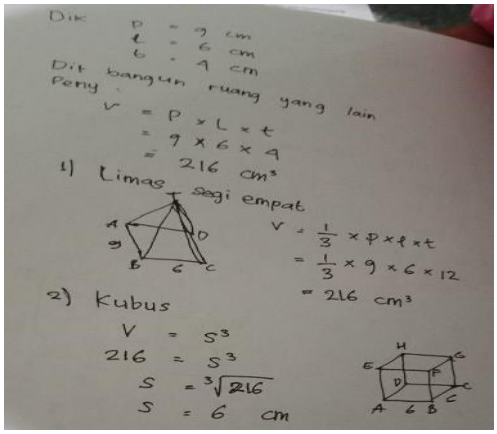


Figure 3 The Answer of the Third Question (S1)

In Figure 3, S1 solved the problem of a system of linear equations using more than one method, namely, by using the substitution, elimination and matrix methods in detail. The solution of the three-variable linear equation system using the matrix used by S1 was a method not used by other subjects. Based on the interview, she expressed several ideas of solving a system of linear equations of three variables and could explain the stages of the process quite well. Therefore, it could be concluded that in the third question, she was able to show all indicators, namely fluency, flexibility, novelty, and elaboration.

Mathematical Creativity of the Second Subject (S2)



In Figure 4, S2 was able to work on the problem even though the solution was less detailed and only used one solution method that was still commonly used by other subjects. Based on the interview, S2 expressed more than one idea to solve the problem, namely, by building a rectangular space and building a cube space and can explain the stages of the process quite well. So, it could be concluded that in the first question, S2 was able to show indicators of fluency and elaboration, although there was no indicators of indicators of flexibility and novelty shown.

Figure 4 The Answer of the First Question (S2)

In the solution to the second question, S2 showed a detailed problem solving even though it only uses one way of solving the problem. Based on the interview, S2 revealed that she only had one idea to solve the problem and the less detailed problem solving. So, it could be concluded that in the second question, S2 was not able to show indicators of creative thinking ability.

In Figure 5, S2 showed a detailed problem solving even though it only used one way of solving the problem. Based on the interview, S2 revealed that she only had one idea to solve the problem, but she could explain problem solving quite well. So, it can be concluded that in the third question, S2 was able to show elaboration indicators, but did not show other indicators.

ICSAT INTERNATIONAL PROCEEDING
ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

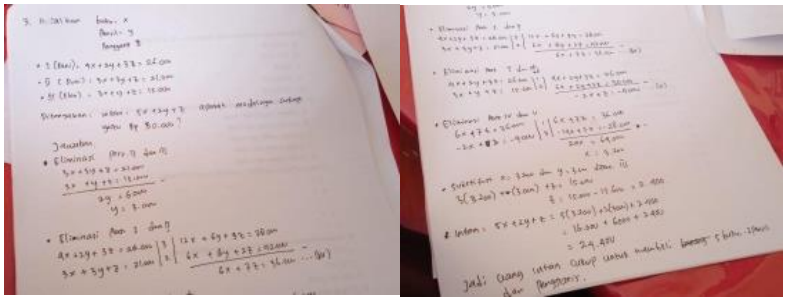


Figure 5 The Answer of the Third Question (S2)

Mathematical Creativity of the Third Subject (S3)

The responses provided by S3 to all three questions were very simple. One of the answers could be seen in Figure 6. All solutions contained only one method which was less detailed. In the interview, S3 revealed no additional explanation to the responses he gave to test items. So, it could be concluded that this student did not show any of the four indicators of creativity.

Mathematical Creativity of the Fourth Subject (S4)

The solutions to the first and the second questions provide by S4 used only one less detailed method. In the interview, this student could not explain richer responses. Therefore, it was hard to identify any of the four indicators of creativity in this student's first two answers. However, a more detailed solution could be observed in the response to the third question. In the interview, S4 revealed that he only had one idea to solve the problem but could explain problem solving quite well. So, it can be concluded that in the third question, S4 is only able to show the elaboration indicator, but has not been able to show other indicators.

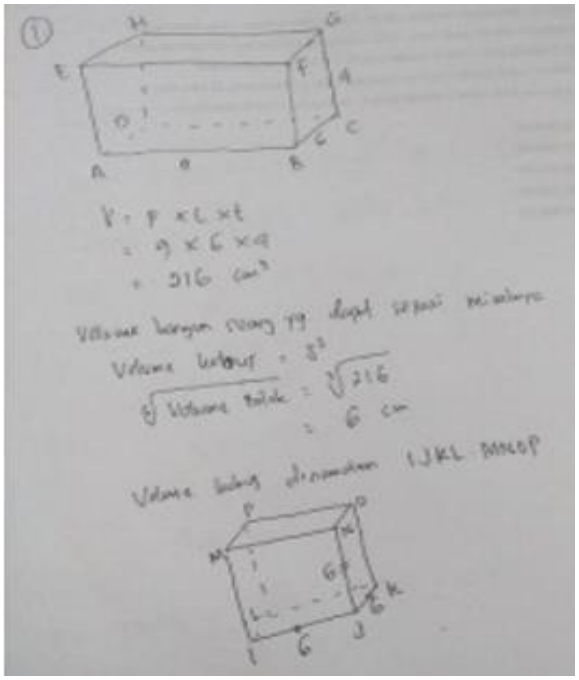


Figure 6 The Answer of the First Question (S3)

Mathematical Creativity of the Fifth Subject (S5)

S5 was able to provide the solutions to the three problems even though they only used one method with a less detailed solution. Based on the interview, this student explained no additional more detailed responses to all the given questions. So, S5 showed no indicators of creativity at all the responses to all question items.

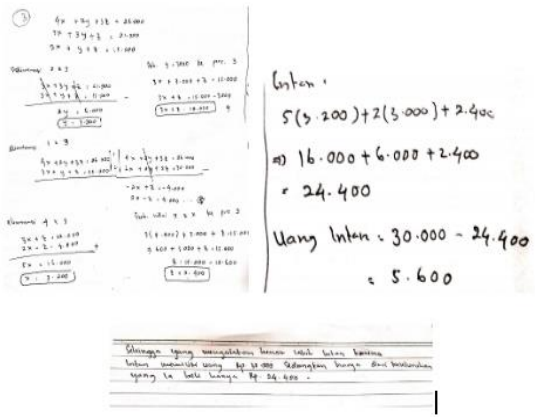


Figure 7 The Answer of the Third Question

ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

Mathematical Creativity of the Sixth Subject (S6)

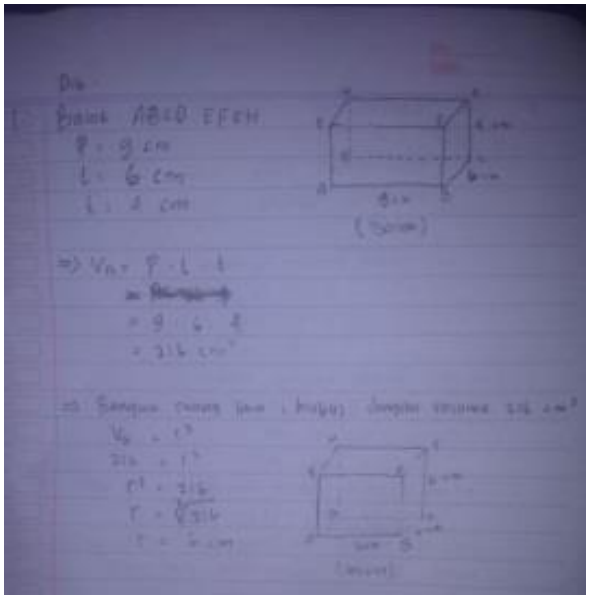


Figure 8 The Answer to the First Question (S6)

The response of subject S6 to the first question showed the detail solution which only used one common method. This student could explain the solution quite well in the interview. However, in all the responses, only one indicator of creative thinking was evident, namely, the elaboration indicator. For the second question, S6 was able to work on the problem with a detailed solution even though it only used one solution method that was still commonly used by other subjects. S6 could express more than one idea to solve the problem and could explain the stages of the process quite well. So, it could be concluded that in this question, S6 was able to show indicators of fluency and elaboration, but not indicators of flexibility and originality. For the third question, S6 was able to show the solution to the problem in detail even though it only used one method with a solution that was still commonly used. Based on the interview, S6 revealed that he only had one idea to solve the problem but could explain problem solving quite well. So, it could be concluded that in the third question, S6 was only able to show the elaboration indicator, but did not show the other indicators.

Discussion

Based on the results of the research conducted, it can be seen that, only one student was able to show the four indicators of creative thinking, namely, fluency, flexibility, originality and elaboration in her problem solutions. This student was from the conditional knowledge dominant group. The following are the scores of the indicators shown by all students along with the classification of the subject's creative thinking ability level.

Based on Table 3 below, it can be seen that for the first question, which is a question about the shape of the space, of two subjects who are able to show indicators of fluency, each of which gave two ideas to solve the problem by building a cube and building a quadrilateral pyramid. The elaboration indicator was also shown by the four subjects where they solved the problem accurately and in detail.

As for the second question concerning flat shapes, only one subject was able to fulfill the fluency indicator, namely by giving two ideas to solve the problem, namely estimating the side of a square on a sheet of plastic. In the first answer, the subject estimated the length of the side of the square as long as the diameter of the large circle. The indicator of originality was also shown by one subject where he estimated the length of the side of the square that was sufficient to cover both circles. The elaboration indicator was shown by two subjects where the subject answered the questions correctly and in detail.

Next, the third question was about a system of linear equations with three variables. One subject could show fluency where in solving a system of linear equations with three variables, she solved problems with two solutions. The indicator of flexibility was shown by one subject where he solved the problem in two ways, namely, by using the elimination substitution method and using a matrix. The novelty indicator was shown by one person where the subject answered the problem in a way that was not commonly used by other subjects, namely, using a matrix in solving a system of linear equations of three variables.

ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

Table 3 The Students' Mathematical Creativity

Subjects	No.	Mathematical Creativity Indicators				Total	Criteria Level of Creative Thinking Skills
		Fluency	Flexibility	Originality	Elaboration		
S1	1	4	2	2	4	12	TKBK 3 (Creative)
	2	4	2	3	4	13	
	3	4	4	4	4	16	
			Total (n)			41	$32 < n \leq 48$
S2	1	4	2	2	4	12	TKBK 3 (Creative Enough)
	2	1	1	1	2	5	
	3	2	2	2	4	10	
			Total (n)			27	$16 < n \leq 32$
S3	1	2	2	2	3	9	TKBK 3 (Creative Enough)
	2	2	2	3	4	11	
	3	1	1	2	2	6	
			Total (n)			26	$16 < n \leq 32$
S4	1	1	1	1	1	4	TKBK 3 (Creative Enough)
	2	1	1	2	2	6	
	3	2	2	2	4	10	
			Total (n)			20	$16 < n \leq 32$
S5	1	1	1	2	2	6	TKBK 3 (Creative Enough)
	2	1	1	2	2	6	
	3	1	1	2	2	6	
			Total (n)			18	$16 < n \leq 32$
S6	1	2	2	2	4	10	TKBK 3 (Creative Enough)
	2	4	2	2	4	12	
	3	2	2	2	4	10	
			Total (n)			32	$16 < n \leq 32$

This research revealed that the student with dominant conditional knowledge had better performance compared to her counterpart students. Someone with this conditional knowledge is the one who knows when and it what circumstances the knowledge he or she has will be used fruitfully (Flavel, 1979). Investigation on metacognition is still continuing, as it is a rather complex construct. The practical implication which could focus is regarding how to develop creative thinking ability from the metacognitive perspective (Jia et al., 2019). Including the metacognitive skills in curricula could be an alternative action (Scott, et al., 2004; Hargrove & Nietfeld, 2015), and a new training perspective which is developed on the base of metacognition knowledge could be considered as well as an avenue for cultivating the creativity of students (Jia, et al., 2019).

CONCLUSIONS

Based on the analysis and discussion, it can be concluded that 1) one subject from conditional knowledge group is able to show all indicators of creative thinking skills well, namely, fluency, flexibility, novelty and elaboration and she could be classified into level 3 (creative), whereas another subject from the same group is able to show 2 indicators, namely, fluency and elaboration and he could be classified into level 2 (creative enough); 2) two subjects each from declarative knowledge and procedural knowledge group are only able to show one indicator, namely, the elaboration and they could also be classified into level 2 (creative enough).

ISBN: 978-623-7496-62-5
Vol, 11 Issue 1

REFERENCES

Baker, L., & Brown, A. L. (1984). Metacognitive skills and reading. In P. D. Pearson (Ed.), *Handbook of reading research* (pp. 353-394). Longman.

Fardah, D. K. (2012). Analisis proses dan kemampuan berpikir kreatif siswa dalam matematika melalui tugas open-ended. *Jurnal Kreano*, *3*(2), 91–99.

Fauzi, Z. (2019). *Tingkatan berpikir kreatif matematis siswa SMP ditinjau dari self-regulated learning* (Unpublished master's thesis). Universitas Pendidikan Indonesia, Bandung, Indonesia.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Hargrove, R. A., & Nietfeld, J. L. (2015). The Impact of Metacognitive Instruction on Creative Problem Solving. *The Journal of Experimental Education, 83*(3), 291–318. https://doi.org/10.1080/00220973.2013.876604

Jia, X., Li, W., & Cao, L. (2019). The role of metacognitive components in creative thinking. *Frontiers in Psychology, 10*, Article 2404. https://doi.org/10.3389/fpsyg.2019.02404

Kholikoh, A. 2016. *Analisis kreativitas siswa dalam menyelesaikan masalah matematika ditinjau dari gaya kognitif field dependent dan field independent di MTs Muhammadiyah Sirampog* (Unpublished undergraduate thesis). Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia.

Ricardo, R., Mardiyana, & Saputro, D. R. S. (2014). Tingkat kreativitas siswa dalam memecahkan masalah matematika divergen ditinjau dari gaya belajar siswa (studi pada siswa kelas IX MTs Negeri Plupuh Kabupaten Sragen semester gasal tahun pelajaran 2013/ 2014). *Jurnal Elektronik Pembelajaran Matematika*, *2*(2), 141–151.

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal, 16*(4), 361–388. https://doi.org/10.1080/10400410409534549

Zakaria, E, Nordin, N. M., & Ahmad, S. (2007). *Trend pengajaran dan pembelajaran matematik.* Utusan Publication & Distribution.