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Self-Determination in Mathematics Learning Process by Using Generative Multi – Representation Learning (GMRL) Model

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Abstract. This research aimed to determine the students' self determination in mathematics learning process and the effect of Generative Multi Representation Learning (GMRL) model on students' self-determination. An experimental research (two equivalent groups) was applied to achieve the goal. The 124 Senior High School students in Jambi Province were selected as the research sample; they were devided into two groups (experimental and control groups).Each group was divided into three categories of students based on their Mathematics Proficiency Level (High, Moderate, and Low). For collecting the data, a self-determination questionaire was administered to the students. GMRL model which consist of three main components: Generative learning; Multi-representation learning; Self-determination theory was applied in experimental group for three months. The control group was treated by conventional teaching method which more focused on teacher's role. The results showed that the students' self-determination in experimental group were significantly higher than those in control group. Further analysis showed that the students' self-determination in each level of mathematics proficiency in experimental group was significantly higher than those in control group. In conclusion, the results of this research indicate that GMRL model is effective in developing students' self-determination and applicable in improving the quality of mathematics learning process.

1. Introduction
The boredom and reluctance to think in the process of learning mathematics is the most common problems found in high school students. Although many students are interested in math, still the abstract of mathematical properties at secondary schools "abort" one by one the mathematics enthusiasts [1]. This is due to the decreased of motivation, determination and spirit of students in learning mathematics. Even the decline of determination in learning mathematics can be found earlier, which is when the process of arithmetic transition and algebra began to occur. These problems are closely related to the students' low self-determination. Therefore, an approach which can maintain and

develop the determination as well as stimulate students' self-regulating in learning mathematics should be a special concern.

Specifically, self-determination is defined as the determination that arises from within a person, which is the consequence of awareness emergence about the importance of something and the belief in the ability of self (optimistic) beyond what is believed before [2, 3, 4, 5]. In line with this, Field & Hoffman [4]statethat self-determination is as an ability to define and achieve goals based on the foundation of values sourced from within itself. In conclusion, self-determination includes cognitive, affective and behavioural factors [4].

In addition, Wehmeyer [6] defines self-determination as "acting as the primary causal agent in one's life and making choices and decisions regarding one's quality of lifefree from undue external influence or interference".Therefore, people who have high self-determination will have high quality in making choices and making decisions, and will be free from undue bad influence. Thus, behaviors adopted by a person tend to show their true desires, not for compulsion or intervention. Furthermore, having self-determination is indicated by reflecting the four essential characters in action, such as: (1) the individual acted autonomously, (2) the behaviors were self-regulated, (3) the individual initiated and responded to events in a psychologically empowered manner, (4) the individual acted in a self-realizing manner, (5) know yourself, (6) experience outcomes and learn [3, 4, 6].

Furthermore, self determination is strongly influenced by two things: (1) Behaviors Regulation; and (2) Human Need [7]. Based on the psychology of needs, humans needat least three things in social context: Competence [8], Relatedness [9] and Autonomy [2]. Awareness of the needs of these three things growed interest, optimism, motivation and determination of a person behave in a certain activity or self-determination.

Moreover, self-determination is a mixture of intrinsic motivation and intrinsic regulation. In other words, when a person has no self-determination (Nonself-Determinated), it is certain that the person is in action and reacting without motivation (amotivation) and non-regulation; in the case of a student's learning in amotivation and non-regulation will exhibit non-serious behaviour, cannot control himself/herself, has no ability to regulate his/her previous knowledge, shows no value, and shows no acquisition of knowledge or competence that is sufficient, pessimistic or feels he/she has no ability to master certain material [10, 11]

Additionally, the positive relationship between self-determination and education (learning outcomes) has been proved by some studies. The relationship between self-determination and learning outcomes occurs at all levels of education from primary school to college [12, 7]. In other words, the desire in determining fate based on the motivation that comes from within has a significant impact on the ability to self-control in accessing knowledge, whether existing knowledge or knowledge being learnt. Such attitudes directly impact the learning outcomes.

Based on the description above, certain treatment which can develop students' self-determination during a learning process is strongly necessary.The self-determination is seen in three categories, they are: amotivated, extrinsically motivated, and instrinsically motivated [5]. In other words, a person's self-determination can consist of one of the three categories. Based on the theory of self-determination, Instrinsically motivated is the highest condition of a person in doing an activity or behave, because with the presence of theintrinsic motivation someone will act with full volunteer regardless of reward obtained. To instils self-determination in a person and make it as a natural behavior, it is necessary to understand the existence of extrinsic motivation that can act as the treatment of the students such as gifts or bonuses, time constraints, supervision, and judgment [5]. Extrinsic motivation is an unnatural motivation in a person or a motivation arising from a treatment, which then gradually becomes a natural behaviour after experiencing the process of internalization; extrinsic motivation consists of four levels: (1) external regulation; (2) interjected regulation; (3)identified regulation; and (4) integrated regulation. In conclusion, some points can be drawn to implement and measure self-determination in this research: self-determination is influenced by: (1) Behaviour Regulation; (2) Human Need, which states that person needs three things: competence, relatedness, and autonomy. Motivation is a major part of the self-determination, then motivation is

divided into two kinds, intrinsic motivation (knowledge, accomplishment, stimulation, interesting, and enjoyment) which is the indicator where someone has had a self-determination [13] and external motivation (external, identified, interjected, and Integrated regulation) which reflects a person in an amotivation or having weak self-determination, or can also be called internalization to self-determination. Based on the background of the theory, therefore in the integration of self-determination into the aspects of learning should consider the external motivation as a treatment; while students' self-determination is measured by considering the four indicators of self-determination.

Table 1. The Four (focus) Indicators of Self Determination.

1. **Know Yourself**		2. **Perceived Choice**	
	a. Know self-ability		a. Consideration in choosing an activity
	b. Know your own emotions		b. Sense of freedomin doing an activity
	c. Self-control		c. Satisfaction of making a choice
3. **Intrinsic Motivation (Competence)**		4. **Intrinsic Motivation (Relation/Relevance)**	
	a. Interest in something new		a. Asking teachers or other students
	b. Following the learning process		b. Answering questions from teachers and other students
	c. Doing tasks/exercises		c. well behaved to friends and teachers
	d. Maintain discipline		d. Not cheating
	e. Persistence / resilience / determination		

The self-determination is the key variable or final goal to be achieved in this research. While the Generative Multi-Representation Learning (GMRL) model is defined as means to achieve the desired goal. In plain view it is not easy to find a connection between Generative and Multi-Representation learning duringthe learning process. However, if it is examined more deeply, Multi Representation and Generative Learning have a systematic relationship. Therefore,between the four generative learning processes(motivation, learning, knowledge, generation)[6, 14, 15] and the three multi-representation learning functions (complement, encouragement, and development)[16, 17, 18] can complement and strengthen, thus able to solve the problematic of mathematical learning which is structural.

In details, thelearning model framework and the interrelationship between the elements of this research is presented in **Figure 1**.
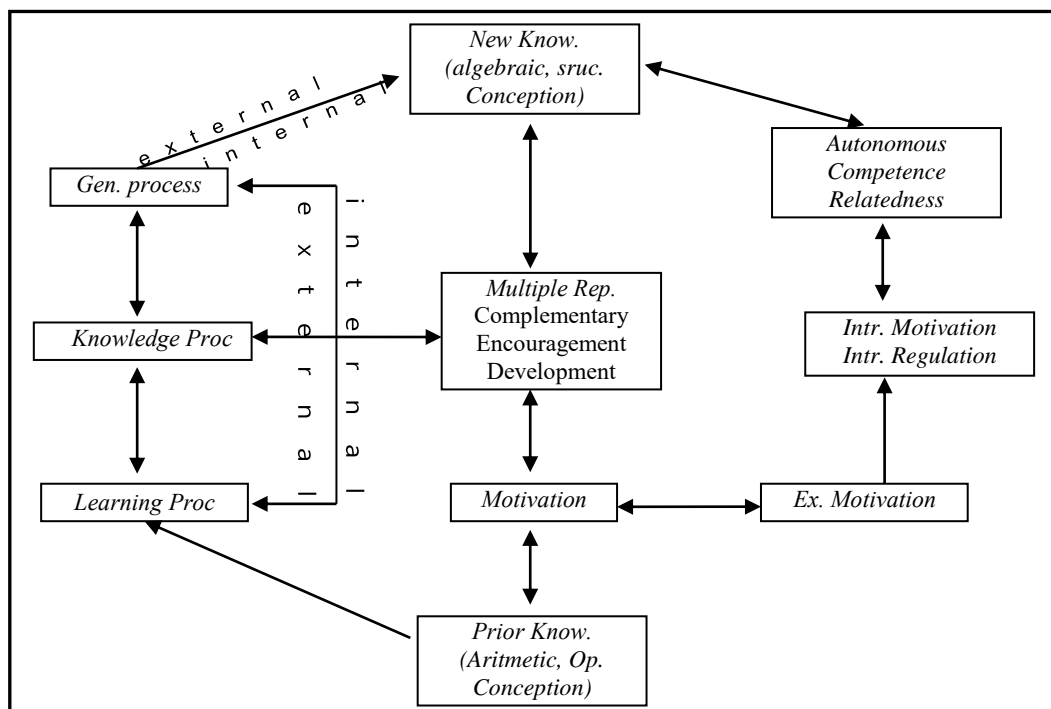
Figure 1. The Framework of Generative Multi- Representation Learning Model.

As presented in **Figure 1**, MultiRepresentation gives a direct influence on the four components of the Generative Learning process. As mentioned earlier, Multi-Representation has three functions in learning, which are:complement, encouragement, and development. Additionally, components of Generative Learning process, after affecting motivation, each of the three functions of Multi Representation directly affect the learning process, knowledge processing process, and knowledge generation process. Furthermore, Multi Generative process of Multi Representation will become extrinsic motivation for students which is one indicator of self-determination. Through a complex process of internalizing knowledge, the learning process automatically generates a set of knowledge that is ready for processing. At a later step, the functions of Multi-Representation will make an important contribution to the internalization of knowledge to generate new knowledge.

Based on the discussion above, whether it is about Generative or Multi-Representation learning, the syntax of Generative Multi Representation Learning in detail is composed as follows.

1. *Preparation*, theresearcherprepared the teaching material, including: analyzing the scope of the teaching material, deciding the topics of the teaching material, analyzing the appropriateness of the teaching material with the students' prior knowledge, learning trajectories and didactic phenomena.

2. *Regulation*, the researcher set the learning rules, scoring system, range and limitations of learning, which were explained to the students before the learning process. For example: the teacher mentioned some of the lesson material related to the material to be studied, either related to the previous material or the relation with the material further.

3. *Motivation*, this is the first step in the context of learning in the classroom. The researcher provided motivation to the students about the importance of skills or competencies contained in the learning. Furthermore, the researcher and the students had a discussion which aimed to know the complaints that were often faced by the students in the learning process and the needs of students throughout the learning process to be implemented.

4. *Learning process,* theresearcher beganthe learning process by giving cases that have been modified into various representations and askedthe students to discuss the cases based on previously

acquired related material, in order to find the mathematical ideas stored in these representations. The teacheralso monitoredthe students' performance and conducteda discussion or dialogue with the students if necessary. Furthermore, the researcher introduced the material to be learnt by linking the relevancy of the new material to the preceding material using an analysis of the representation given earlier. The results ofstep 1 to 3 were used entirely to reinforce the learning process.

5. *Learning process*(*reinforcement*), the researcher gavefeedback to the students' opinions by connecting facts that have existed in students' minds with new facts that reinforce students' belief in the effort to understand new concept; then the researcher introduced new concept starting from concept development previously by linking the similarity and character of the two concepts. The researcher asked the students to find the representations that could be attributed to the new concept in various representations that could be done by the students; at this stepthe students were given a freedom to choose and define the representations used.

6. *Learning process*(building knowledge), the researcher provided new issues that have not been encountered in the learning process to be solved by using existing facts, and askedthe students to find a solution in accordance with the problems or phenomena given; at this stepthe students were expected to be able to analyze the representations they use. The Students were also asked to provide arguments about the results of the work they undertake, as the evidence for the construction or mastery of a new concept;

7. *Assessment*, at this step the researcher assessed the learning that has been done by using an instrument of assessment in the form of questions that have been prepared previously. The assessment can also byanalyzingthe students' performance throughout the learning process.

As described in thesteps above, the researcher's roleduringthe learning processwas in the role of discussion, dialogue, provide a help (scaffolding) to the students and seek the right timing to provide it without any discrimination or excessive intervention, in accordance with the principle of generative learning. One point that needs to be underlined is that the above steps can be run spirally or repeatedly to create the desired learning process. In addition, the steps aboveare common steps that can be used on any subject matter. Therefore, it must be oriented to the material, motivation, competence and indicator of learningin applying GMRL.

2. Methodology

Thisisa quantitative research with an equivalent two-group experimental model. The124 high school students in Jambi Province were selected as the sample of the research; the students were divided into two groups (a control group which the students were taughtusing conventional teaching method; and an experiment group which was taught using GMRL Model) [17]. The students' mathematics proficiency level was used as the consideration in dividing the group. In addition, each group consisted of the students with Low, Moderate, and High level of mathematics proficiency;it was aimed to see if the GMRL model gives a different effect on each level of mathematics proficiency (Low, Medium, and High).

After completing the treatments, the students were given self-determination questionnaire to measure their self-determination in each indicator of self-determination. The questionnaire results then analysed and presented descriptively. Furthermore, the data were processed using statistical analysis to see the self-determination differences between experiment and control group. For the purpose of statistical analysis, the ordinal data were compared to interval data using the Method of Successive Interval (MSI).

To determine the effect of GMRL model on the students' self-determination, the difference of the self-determination mean scoresin each group (experimental-control) wereanalyzed and categorized into several indicators. The steps in analyzing the difference score were: (1) normality test of both groups using Shapiro Wilk; (2) if the data is normally distributed, then it is followed by homogeneity test by using Levene test; (3) If the data shows a homogeneous distribution, then the parametric test will be applied using the independent t-test, to see the mean difference between experimental and

control groups; (4) if the assumption of normality is not met at step 2, thennon-parametric analysis by using Mann Whitney U test would be used to see the mean difference between experimental and control group.

3. Results and Discussion

3.1. Descriptive Analysis
The summary of the descriptive analysis of the mean score of the students' Self-Determination based on the Mathematical Proficiency Test (MPT) is presented in **Figure 2.**
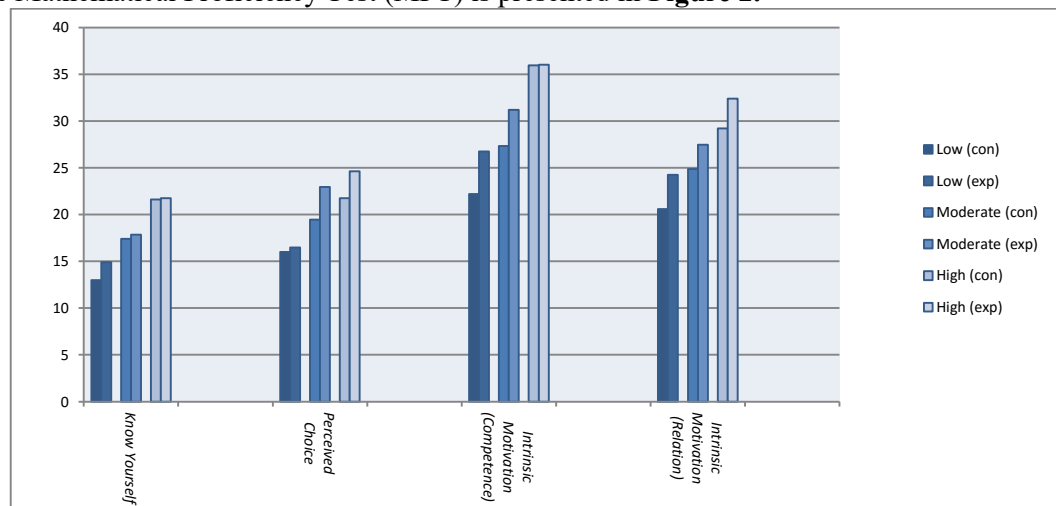

Figure 2. The Mean Score of the Students' Self-Determination Based onThe Mathematical Proficiency Test (MPT).

3.1.1   Know Yourself
As Presented in **Figure 1**, descriptively the mean score of the indicator of Know Yourself in alllevels of MPT (Low, Moderate,High) in Experimental group (Low = 14.89, Moderate = 17.86, High = 21.75) is higher than the mean score in control group (Low = 13.00; Moderate = 17.40; High = 21.60.This clearly proves the superiority of the GMRL model in influencingstudents' self-determination in the indicator of Know Yourself.

3.1.2   Perceived Choice
Besides, there is also a different in mean score on the indicator of Perceived Choice in all levels of MPT (Low, Moderate and High) between the experimental group (low = 16.47; Moderate = 22.93; High = 24.63) and control group (Low = 16.00; Moderate = 19.47; High = 21.73). This result then clearly demonstrates the superiority of the GMRL model in influencing students' self-determination on the indicator of Perceived Choice.

3.1.3   Intrinsic Motivation (Competence)
Furthermore, the mean scores on the indicator of Intrinsic Motivation (Competence) in all of levels of MPT (Low, Moderate and High) show that the mean score of experimental group (Low = 26.74; Moderate = 31.18; High = 36.00) is higher than the mean score of control group (Low = 22.18; Moderate = 27.33; High = 35.93). Again, this result clearly verifies the superiority of the GMRL model in influencing students' self-determination in the indicator of Intrinsic Motivation (Competence).

3.1.4   Intrinsic Motivation (Relation / Relevance)

Lastly, the mean scores on the aspect of Intrinsic Motivation (Relation / Relevance) in all levels of MPT (Low, Moderate and High) as well show that the mean score of experimental group (Low = 24.26; Moderate = 27.46; High = 32.38) is higher than the mean score of control group (Low = 20.59; Moderate = 24.87; High = 29.20). Therefore, this result clearly demonstrated the superiority of the GMRL model in influencing students' self-determination in the indicator of Intrinsic Motivation (Relation / Relevance).

3.2. Statistical Analysis

Table 2. The Results of Statistical Analysis.

No	Indicator	Level of MPT	Group	*Saphiro Wilk*	*Levene Test*	*t-test*	*Mann Whitney U*	Mean/ Range Difference
1.	Know Yourself	Low	Control	.005	-	-	0,014	Significant
			Experimental	.060				
		Moderate	Control	0,271	0,207	0,514	-	Significant
			Experimental	0,056				
		High	Control	.114	-	-	0,452	Significant
			Experimental	.004				
2.	Perceived Choice	Low	Control	.213	0.531	0.004	-	Significant
			Experimental	.956				
		Moderate	Control	0,638	0.581	0.000	-	Significant
			Experimental	0,502				
		High	Control	0,095	0.647	0.000	-	Significant
			Experimental	0,101				
3.	Intrinsic Motivation (Competence)	Low	Control	0,078	0.500	0.0015	-	Significant
			Experimental	0,538				
		Moderate	Control	0,054	0.657	0.002	-	Significant
			Experimental	0,339				
		High	Control	0,126	0.975	0.000	-	Significant
			Experimental	0,444				
4.	Intrinsic Motivation (Relation/Relevances)	Low	Control	0,394	0.797	0.004	-	Significant
			Experimental	0,954				
		Moderate	Control	0,297	0.856	0.0115	-	Significant
			Experimental	0,058				
		High	Control	0,393	0.686	0.002	-	Significant
			Experimental	0,164				

As presented in **Table 2**, the mean score of the students' self determination in all indicators of the self-determination is significantly different between experimental and control group; the significant difference is also found in all levels of MPT. Furthermore, the results of descriptive analysis (see **Figure2**) indicate that the students' self-determination in experimental group is higher than those in control group in all indicators of self-determination and all levels of MPT. Furthermore, some interpretations due to the findings of this research are presented below.

The results of statistical analysis indicate that the GMRL model is effective in influencing students' self-determination after they were taught for three months. This result is inline with a research finding conducted by Byman [20] who found that students' intrinsic motivation is promoted by giving the students choice and supporting their autonomy. At the step of learning process in GMRL model, the students were given freedom or multi representation to choose any ways to solve their difficulty in understanding a topic of learning material, such as having discussion with the teacher or other students. Therefore, the students could choose an effective way to solve their problem which is appropriate with their understanding. As discussed previously, intrinsic motivation could appear once the students have autonomy; meaning that the students have aware that they learn something because it is based on their need. Additionally, the relationship among the indicators of self-determination is presented in **Figure 3**.
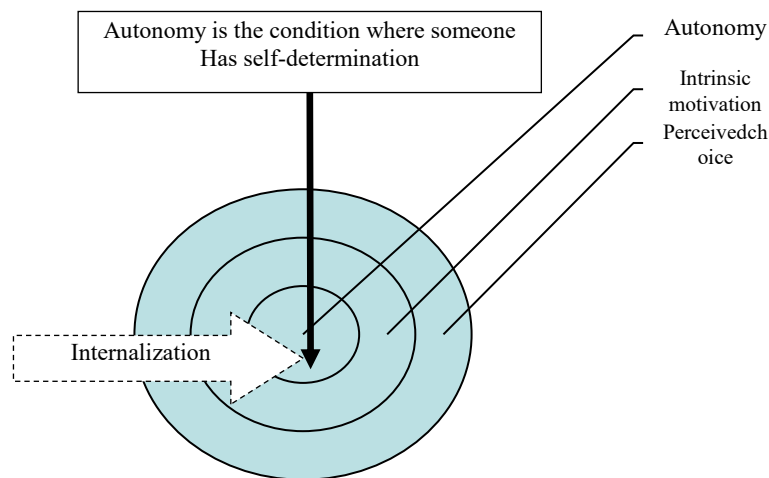
Figure3. The Internalization Process of Self-Determination

As presented in **Figure3**, the process of developing self-determination requires some steps which should be concerned by a teacher in a learning process. During the implementation of the GMRL model, the researcher has applied some steps which support the internalization of self-determination. Before coming to the learning process, the researcher gave motivation in order to internalize students' awareness about the importance of the topic and the knowledge included in the topic that will be discussed. This is important because as the theory proposed by Byman [20], instructing students by using motivation regulation strategies may provide them with the tools they need to self-regulate the level of effort and persistence given to academic tasks more effectively. In line with this, Guay [13] states that the students who are regulated by autonomous motivations experience positive consequences (behavioural, cognitive, or affective) at school.

4. Conclusion

Based on the results and the discussion above,several conclusions can be drawn. First, the GMRL model is effective in internalizing students' self-determination. A better achievement in the experimental group of students' self determination occurs in all indicators of self-determination, which are: Know Yourself; Perceived Choice; Intrinsic Motivation (Competence); Intrinsic Motivation (Relation/relationship). Moreover, in each level of MPT (Low, Moderate, and High), the students' self-determinationin experimental groupis higher than those in control group.

Second, despite of having significant difference in self-determination, the result of descriptive analysis showed that there is still a slightly different in self-determination between experimental and control group. The researcher recommends that to achieve better achievement of self-determination, it requires a longer duration of treatment. The process of planting the attitude of self-determination should take place in a long time vulnerable because of the external motivation to the intrinsic motivation required internalization of regulations that certainly takes a long time[2, 3, 7]. In other words, if the duration of the study is longer it will certainly also show the achievement of a better attitude of self-determination in the experimental group.

Third, this research has proved that GMRL model gives positive influence on students' self-determination. As proposed by some theories, by having high self-determination, the students' can achieve better academic achievement including mathematics. Therefore, it is strongly suggested that

mathematics teachers apply the GMRL model as an alternative learning model in teaching mathematics which is abstract [1].

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6. References

[1]. A. Sfard1991OnThe Dual Nature of Mathematical Conceptions: Reflections on Processes and Objects as Different Sides Of the Same Coin *Educational Studies in Mathematics* 22, 1-36.

[2]. E LDeci1975*Intrinsic Motivation*. New York: Plenum.

[3]. E LDeciand Ryan M Richard1985*Intrinsic Motivation And Self-Determination In Human Behavior*. Springer Science+Bussines& Plenum Press, New York.

[4]. SField andAHoffman1994Development of a model for self-determination. *Career Development for Exceptional Individuals,* 17, p159-169.

[5]. Gagneˊ and E L Deci2005Self-Determination Theory and Work Motivation. *Journal of Organizational Behavior*26, p 331–362.

[6]. MCWittrock1974Asa Generative Process. Educational Psychologist, 19(2), p 87–95.

[7]. ELDeci,JRobert,Vallerand, L G Pelletier, and Richard M Ryan1991 Motivation and Education: The Self-Determination Perspective. *Educational Psychologist*, 26(3&4), p 325-346.

[8]. SHarter 1978EffectanceMotivation Reconsidered: Toward a developmental model. *Human Development*, 1, p661-669.

[9]. R Baumeister andM. R. Leary1995 The Need to Belong: Desire for Interpersonal Attachments As A Fundamental Human Motivation. Psychological Bulletin, 117, p497-529.

[10]. A Bandura1986 Social Foundations of Thought and Action: A Social Cognitive Theory. Englewood Cliffs, NJ: Prentice-Hall.

[11]. R MRyan andDeci, EL2000 Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychological Association*, 55(1), p 68-78.

[12]. HDaoust, RJVallerand, andMRBlais1988Motivation and Education: A look at some important consequence*s. Canadian Psychology*, 29, p172.

[13]. FGuay, C FRatelle andJulienChanal2008Optimal Learning in Optimal Contexts: The Role of Self-Determination in Education. *Canadian Psychology*. 49(3), p 233–240.

[14]. C AWittrock, 1974A Generative Model of Mathematics Education. *Journal for Research in Mathematics Education,* 5(4), p181–196.

[15]. M C Wittrock1990Generative Processes of Comprehension. *Educational Psychologist*, 24, 345–376.

[16]. S EAinsworth1999 A Functional Taxonomy of Multiple Representations.*Computers and Education*, 33(2/3), p131-152.

[17]. RLesh, TPost andMBehr1987Representations and translations among representations in mathematics learning and problem solving. Problems of Representation in the.*Teaching and Learning of Mathematics,*p33–40.

[18]. D GMallet2007 Multiple representations for systems of linear equations via the computer algebra system Maple. *International Electronic Journal of MathematicsEducation.* 2(1). p16-32.

[19]. LVicki, Plano Clark and W John Creswell2015 Understanding Research: A Consumer's Guide (Second Edition). New Jersey, USA: Pearson Education, Inc.

[20]. ReijoByman and PerttiKansanen2008 Pedagogical Thinking in a Student's Mind: A Conceptual Clarification on the Basis of Self-Determination and Volition Theories. *Scandinavian Journal of Education Research,* 52 (6). 603-621.

[21]. MLWehmeyer1996 *Self-determination as an educational outcome: Why is it important to children, youth and adults with disabilities?* In D. J. Sands & M. L. Wehmeyer (Eds.), Self-determinationacross the lifespan: Independence and choice for people with disabilities (p 15-34). Baltimore: Paul H. Brookes.