Utilizing Learning Analytics to Investigate the Impact of Using Self-Regulated Learning: What is the influence on Students' Thinking Ability and Ethics?

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ABSTRACT
Self-regulated learning (SRL) is a method of learning in which a learner sets goals, controls and manages his learning, and evaluates himself. Learning Analytics (LA) was used to see the extent of SRL's impact on students' higher-order thinking skills. This study aims to examine the role of LA in examining students' thinking ability about Higher-order thinking skills (HOTS) and ethics in an SRL context, and we explore differences in student HOTS. The samples involved 44 students of a suburban high school, Junior High School 2 Delima, Pidie Regency, selected by purposive sampling. This research is an ex post facto study. As such, this research data measures high-level thinking abilities (HOT) that have occurred before. Prior knowledge data were collected from initial tests, while SRL is by questionnaire. Data were analyzed using the MANOVA test. The results showed a relationship between SRL and the ability to solve HOT questions. There is no interaction between SRL and variation of students' initial abilities to improve students' HOTS. Thus, the increase in HOT problem-solving ability was caused by differences in students' SRL, not because of prior knowledge. In other words, there is no mutual influence between students' SRL variations and their initial mathematical abilities. The findings based on the interviews revealed that students with good SRL are able to solve HOT problems with a score of 80-100.

Keywords: *Self-regulated learning, Learning analytics, HOTS, ethics, ex-post facto*

1. INTRODUCTION

The current study used Learning Analytics (LA) to examine students' Self-Regulated Learning (SRL) and its impact on their thinking skills and ethics. This study also explores the relationship between students' SRL and thinking skills, such as HOTS. The field of LA is attractive due to the possibility of using large volumes and a variety of data that enhance the vision of substantial improvements in teaching and learning practices in an optimized and scalable way [1].

LA consists of collecting, analyzing, and reporting data to understand better an environment where learning takes place and optimize it [2]. In LA, the characteristics of learners are crucial for optimizing the learning process to support students' learning performance [3]. LA can promote educators' understanding of students' learning experience with technology such as games or other online tools, which enrich students' learning experience, e.g., [4]. LA presents opportunities to enhance the quality of education by capturing, analyzing, and visualizing learning and teaching behaviours [5].

One of the student behaviours in the learning process is learning regularity. Learning regularity is a recursive or repetitive cycle of cognitive activity that involves analyzing tasks, selecting, adopting, or finding strategies to achieve them, and monitoring the results [6]. Furthermore, the learning regularity in this paper is called Self-Regulated Learning (SRL). SRL is an active and constructive process, namely diagnosing learning needs by regulating and controlling performance, cognition, motivation and behaviour to see difficulties as a challenge so that students can evaluate the process and learning outcomes of a learning process [7]. The indicators of self-regulated learning are: (1) having the initiative and motivation to learn, (2) diagnosing learning needs,(3) viewing a difficulty as a challenge,(4) setting learning goals or targets, (5) choosing and implementing learning strategies, (6) monitoring, organizing, and controlling learning, (7) utilizing and finding relevant sources, (8) evaluating learning processes and outcomes, and (9) self-concept or self-ability [7].

2. LITERATURE REVIEW

There is some literature on the aim of Learning Analytics (LA), namely, LA is the (1) measurement, (2) collection, (3) analysis and (4) communication/reporting of data about students and their contexts, with the aim of

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understanding and optimizing learning and the environments where it takes place, helping teachers in their teaching process, as it is possible to make early pedagogical decisions due to predictions and better data visualization [8]. There are five dimensions of qualitative indicators in Learning Analytics assessments: a) objectives (awareness, reflection, motivation, behavioural change); b) learning support (perceived usefulness, recommendation, classification of activities, detection of students at risk); c) measures of learning and outcomes (comparability, effectiveness, efficiency, usefulness); d) data aspects (transparency, data standards, data ownership, privacy); and, e) organizational aspects (availability, implementation, training of educational stakeholders, organizational change) [9].

2.1 Measurement

Measurement signifies that with its indicators, LA examines the extent of the role of Self -Self-regulated learning (SRL) in improving higher-order thinking skills (HOTS). Does student motivation increase? Is there a change in learning behaviour? Is his perception of HOTS distorted? Is there any effectiveness and efficiency in using SRL? To realize this, we use expert literature. SRL is one of the crucial individual sub-factors contributing to learning [10]. SRL in mathematics also has a significant role in adapting to learning in the new normal and influences students' mathematical learning outcomes [11].

SRL is an active and constructive process, namely diagnosing learning needs by regulating and controlling performance, cognition, motivation and behaviour to see difficulties as a challenge so that students can evaluate the process and learning outcomes of a learning process [6]. The indicators of self-regulated learning in this study are: (1) having the initiative and motivation to learn, (2) diagnosing learning needs, (3) viewing a difficulty as a challenge, (4) setting learning goals or targets, (5) choosing and implementing learning strategies, (6) monitoring, organizing, and controlling learning, (7) utilizing and finding relevant sources, (8) evaluating learning processes and outcomes, and (9) self-concept or self-ability [7]. Lastly, experts describe that SRL involves three main phases: designing the learning, monitoring the progress while implementing the design, and evaluating the outcomes as a whole [12].

There are seven questions in the interview based on Zimmerman and Schunk [13], as listed below:

1. Designing the learning:
   - How many hours do you study in a day?
   - Do you specify the study time?
2. We are monitoring the learning progress while implementing the design.
   - Do you do the post-test given by the teacher?
   - How do you select formulas and organize problems?
3. Evaluating the learning outcome as a whole:
   - What are the learning strategies you used in solving the problem?
   - When you experience difficulties, do you look for the textbook's solution, ask your friends or wait for them to be discussed in the classroom?
   - Do you have a target to solve the problem? Do your parents care about your school task?

2.2 Collection

Collection means collecting data about the role of SRL in improving higher-order thinking skills (HOTS) and then the interaction between SRL and prior knowledge of HOTS. HOTS includes the ability to analyze and evaluate critical, logical, and creative thinking, problem-solving, decision-making, and meta-cognitive abilities [13], [14]. The 21st-century skills or 4Cs have been regulated by law that educators, teachers, and lecturers must have these four skills. The National Education Association has identified 21st-century skills as "The 4Cs" skills, including creativity, communication, collaboration, and critical thinking [15], [16].

Therefore, the purpose of HOTS is to improve students' thinking skills at a higher level, especially those related to the ability to think critically in accepting various types of information, think creatively in solving a problem using knowledge and make decisions in complex situations. The concept of high-order thinking skills is based on several opinions, namely Anderson and Krathwohl [17]. A revision of Bloom's Taxonomy states that indicators to measure higher-order thinking skills include analyzing (C4), namely the ability to separate concepts into several groups components and relate to each other to gain an understanding of the concept as a whole, evaluating (C5), namely the ability to determine the degree of something based on specific norms, criteria or standards, and creating (C6), namely the ability to combine elements into a new form that is whole and broad or make something original. Below are presented HOTS indicators, summarized based on the opinions of experts.

Table 1. HOTS Aspect and Indicators

HOTS Aspect	Indicators
Creatively	Able to design something to solve problems that occur in the surrounding environment.
	Able to combine various problem-solving according to existing information, then formulate the right strategy to solve the problem.
Critically	Able to examine and detail various problem variables appropriately, then formulate problems and resolution steps properly.
	Able to judge, reject and support an idea, then give

HOTS Aspect	Indicators
	accurate reasons why he rejects and supports the idea.
Communication	Able to communicate effectively to the audience.
	Proposing a robust supporting argument that can be accepted logically.
Collaborative	Able to work in teams.
	Be actively involved in group discussions.

Regarding prior knowledge, each student has a different initial knowledge level in mathematics. Some students have high, medium and low initial knowledge. This affects their ability to understand mathematics. Dick and Carey [18] stated that "initial abilities are the knowledge or skills that students already have before they take the subjects given". So, it can be said that mastery of previous material is a bridge for students in studying subsequent mathematics material. In this research, students' initial abilities mean initial abilities based on students' pre-test scores in the previous material with high, medium and low criteria.

2.3 Analysis

Analysis means revealing the problem, examining the information appropriately and detailing the steps to resolve it to show the relationship between SRL, HOTS and prior knowledge, both quantitative and qualitative.

2.4 Communication/Reporting

Communication or reporting data means visualizing data on the results of the student learning process, both oral and written, through graphs, tables or diagrams to evaluate the learning process so that it is easy to understand the success indicators.

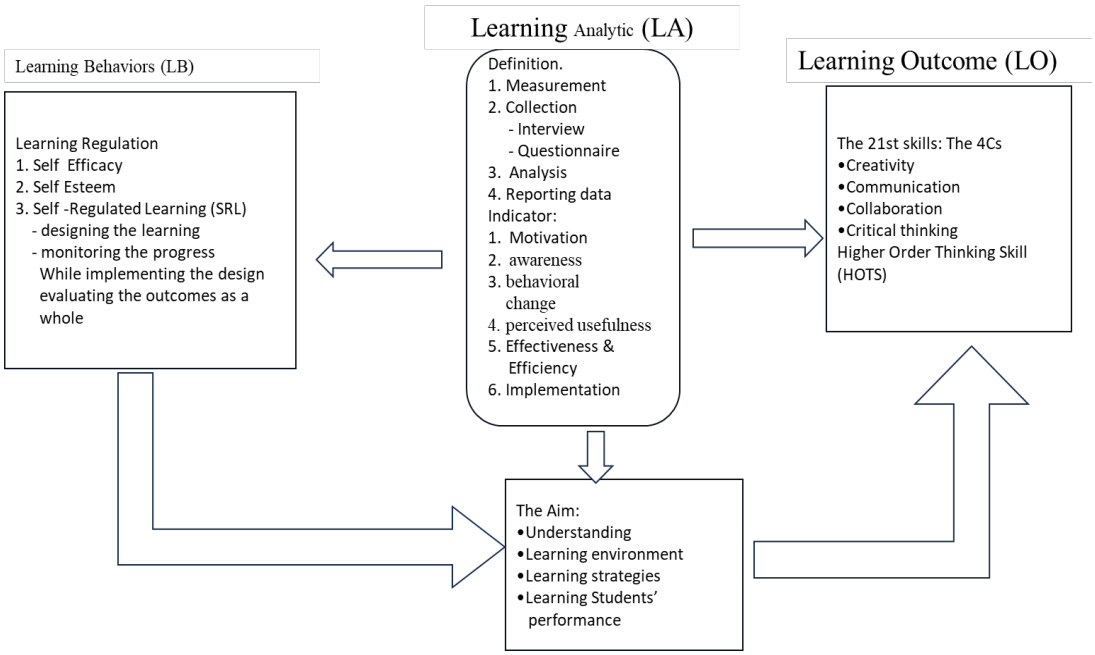

Figure 1. Relationship between LA, SRL and HOTS

3. RESEARCH METHODS

3.1 Research Design

The type of this research is ex-post facto, meaning that the researcher does not manipulate the variables in the study because he is sure that the treatment of the independent variables has occurred before with the one-group pretest-posttest research design. As such, data about student HOTS already existed before. SRL and student perceptions were collected through questionnaires, while prior knowledge was gathered through initial tests. This research is an ex-post facto study, meaning that empirical findings are carried out systematically where researchers do not control for independent variables because their manifestations have occurred or these variables cannot be inherently manipulated.

3.2 Participants and Data Analysis

The samples involved 44 students of a suburban high school, SMAN 2 Delima, selected by purposive sampling. The data was collected through pre-tests, post-tests and questionnaires. Pre-tests were carried out to assess students' prior knowledge. Based on this, students were divided into three groups. This

categorization aims to examine whether there is an effect of the SRL students with different prior knowledge backgrounds. Post-tests used documents of students' high-level thinking learning results that had been carried out by researchers several weeks earlier on the topic of Geometry with four Higher-Order Thinking (HOT) problems, including (1) creative thinking, (2) problem-solving, (3) critical thinking, and (4) communication. Measuring students' SRL using seven questions in the interview based on Zimmerman & Schunk (2001), meanwhile, to find out the extent of LA's function and role in measuring SRL's success in increasing HOTS through motivation, behavioural change, perceived usefulness, and effectiveness. Two variables were measured using a questionnaire, namely motivation and behavioural change adopted from the perception scale by [19], which has been theoretically validated by three educational experts, while two more variables, namely perceived usefulness and effectiveness, use post-test data.

All instruments used in this research have been validated by experts, and field trials have been carried out with valid and reliable results. The quantitative data analysis technique uses a two-way ANAVA test.

4. RESULTS AND DISCUSSION

4.1 Results

The study investigated the impact of using SRL on students' thinking ability and ethics through Learning Analytics (LA). The results are reported under three main headings, which are: 1) the effect of the SRL on HOTS and explore differences in student HOTS according to the interaction between SRL variations and prior knowledge, 2) the role of LA on five qualitative indicators, there are a) objectives (awareness, reflection, motivation, behavioural change); b) learning support (perceived usefulness, recommendation, classification of activities, detection of students at risk); c) measures of learning and outcomes (comparability, effectiveness, efficiency, usefulness); d) data aspects (transparency, data standards, data ownership, privacy); and, e) organizational aspects (availability, implementation, training of educational stakeholders, organizational change). Only four were studied in this research: motivation, behavioural change, perceived usefulness, and effectiveness.

Table 2. Recapitulation of Students' HOTS scoring based on prior knowledge and SRL

Students Score in Prior Knowledge, HOTS and SRL													
No	**Name**	**High (n=10)**			**No**	**Name**	**Moderate (n=21)**			**No**	**Name**	**Lower (n=13)**		
		Pre-test	**Post-test**	**SRL**			**Pre-test**	**Post-test**	**SRL**			**Pre-test**	**Post-test**	**SRL**
1	FI	50	83	80	1	MS	38	65	76	1	MF	33	56	77
2	IK	50	80	79	2	SN	40	72	78	2	IK	38	58	78
3	MA	50	85	82	3	VN	38	62	80	3	SA	36	57	72
4	MF	51	80	86	4	DE	42	69	77	4	ML	35	56	72
5	RA	51	86	84	5	KH	40	63	72	5	LA	34	58	77
6	SA	50	80	82	6	ZA	48	64	78	6	MJ	34	57	68
7	SI	50	72	79	7	MI	42	70	73	7	YN	34	56	71
8	SZ	50	76	81	8	RO	38	68	73	8	NH	35	58	77
9	SR	52	82	79	9	RA	38	65	78	9	JA	35	58	68
10	VE	52	83	82	10	SE	43	80	72	10	YP	35	58	77
					11	LI	40	69	77	11	NU	36	58	72
					12	NA	38	65	80	12	RA	36	60	70
					13	IN	43	73	78	13	AZ	34	58	68
					14	RE	41	65	76					
					15	SH	42	67	78					
					16	AL	43	65	80					
					17	YI	44	75	77					
					18	AN	46	78	72					
					19	US	42	66	78					
					20	AU	48	67	73					
					21	EV	42	67	76					
		50.6	80.7	81.4			41.2	68.3	76.3			35.1	57.5	72.8

Table 3. The Recapitulation of Two variables scoring based on Students' Perception

Aspect	Items	Scale (1 – 5)	
		Score	Average
Attractiveness	Offline discussion is an interesting activity	3.83	3.90
	Practice questions are interesting to learn offline	3.93	
	Teaching materials are interesting to learn offline	4.00	
	I get confused about which part of mathematics needs to be re-studied	3.80	
	I am interested in participating in mathematical olympiad.	4.01	
Easiness	Communicating with peers and lecturers in offline classes can be done easily	3.82	3.59
	I can easily participate in offline learning	3.51	
	Learning tools in offline classes can be found easily	3.82	
	Practice questions in the offline class can be learned easily	3.55	
	I have difficulty with ICT/internet skills to solve the mathematics problem	3.35	
	Overall, face-to-face learning can be easily followed without any significant obstacles	3.44	
Benefits	My learning strategy is appropriate to all mathematical topics.	3.72	3.78
	Offline learning activities improve my concept mastery	3.81	
	Problem-solving activities improve my concept mastery	4.00	
	I became more motivated to attend lectures using attractive methods.	3.80	
	Comparing the mathematical abilities possessed with the targets that must be achieved helps regulate my learning strategy	3.59	
	My interest in solving challenging problems increases my self-directed	3.89	
	Overall, learning mathematics without a target lightens the burden on mind	3.57	

4.2 Discussion

4.2.1 Interaction between Self-Regulated Learning and Prior Knowledge

The interaction between SRL and Prior Knowledge is explained from the recapitulation of the results of testing the null hypothesis with multivariate ANOVA (MANOVA), as listed in Table 4.

Table 4. Interaction between Prior Knowledge and SRL on HOTS

Effect	df	Value	F	Sig.	Decision H_0
Intercept	2	29.281	4201.84[a]	0,000	Rejected
Prior knowledge (PK)	2	0.342	49.199[b]	0,000	Rejected
Self-Regulated Learning (SRL)	2	0.046	6.627[b]	0,002	Rejected
PK * SRL	4	0,056	4.057[b]	0.003	Rejected

Remark: This calculation was executed using Roy'

In the table above, the analysis is given below.

1. The effect of SRL and prior knowledge on HOTS is significant ($p<0.05$). This means students' higher-order thinking skills differ significantly from prior knowledge and SRL. Students' HOTS differ significantly in terms of the interaction between SRL and prior knowledge. This is due to the significance value of each variable, namely $p<0.05$. Graphically, it is presented in Diagram 2. Of the three research groups, the HOTS of SRL 1 group students was better than the other two groups, although this happened to students with low and medium initial knowledge; for students with high initial knowledge, this ability was almost the same for students at SRL 2.
2. There is no interaction between SRL and variation of students' initial abilities to improve students' HOTS. These results are in accordance with the findings of [20], mentioning there is no interaction between SRL and variation of students' initial abilities to improve students' HOTS.
3. The increase in HOT problem-solving ability is caused by differences in students' SRL, not because of prior knowledge. In other words, there is no joint influence between variations in students' SRL and their initial mathematical abilities.
4. Based on Table 1, Self-Regulated Learning (SRL) in the good category is able to solve HOT questions with a score of 80-100.

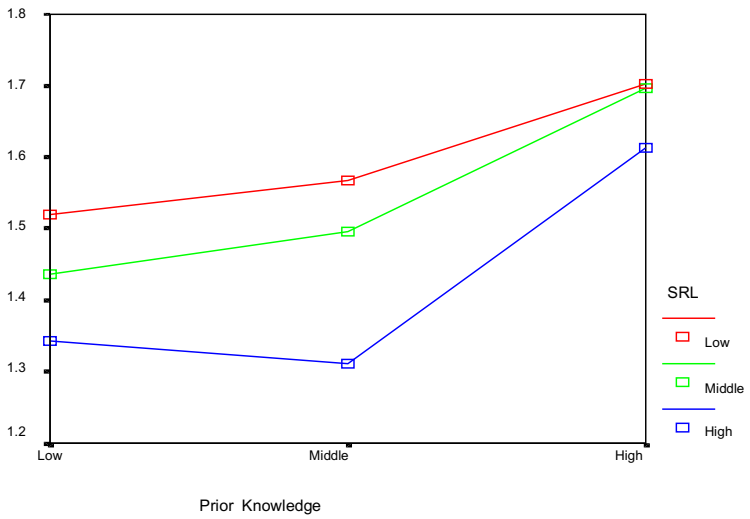

Figure 2. Interaction Between Self-Regulated and Prior Knowledge

5. CONCLUSION

As a group, the high-level thinking abilities of students with high Self-Regulated Learning (SRL) tend to have higher average abilities than students with medium and low SRL, which are significantly different. There are differences in students' high-level thinking abilities based on the interaction between:

SRL variation and prior knowledge. This means that students' higher-level thinking abilities do not only depend on students' prior knowledge but also depend on students' SRL. Students with high initial knowledge and SARL also gain better abilities than students with the same initial knowledge but with medium and low SRL categories. So, the increase in HOT problem-solving ability was caused by differences in students' SRL, not because of prior knowledge. In other words, there is no mutual influence between students' SRL variations and their initial mathematical abilities. Student motivation can be seen in Table 3, namely 3.92 or equivalent to 78.4 (good), while behavioural change is 4.12 or equivalent to 82.4 (very good), and perceived usefulness is 3.87 or equivalent to 77.4 (good).

AUTHORS' CONTRIBUTION

Author 1 contributes to conceptualization, data analysis, and writing. Author 2 assists in reviewing and editing. Author 3 helps in editing and data collection.

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