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Learning Analytics in Mathematics: A Systematic Review

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Abstract
Learning analytics (LA) is a useful approach in helping teachers to interpret the data obtained from students. Applying LA in Mathematics is also an effective approach for teachers to understand their students in depth. The objective of this systematic review is to look at LA applications and their benefits in teaching and learning Mathematics. Systematic review allows researcher to perform a clear examination of LA and Mathematics using systematic and explicit methods. The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) approaches that cover resources from Scopus and Web of Science are applied in implementing a systematic review process, selection criteria and exceptions. As a result, 30 studies which related to LA and Mathematics have been reviewed. Review findings show that the LA approach in Mathematics is frequently applied in improving the quality of the teaching and learning process. In this context, the improvement of the quality of teaching is seen through the improvement of the quality of learning materials, the ability to see the development of learning, and the improvement of student attitudes and behaviors towards Mathematics. LA's benefits in Mathematics education allow teachers to predict student achievement and the risk of dropout of students in learning. Proposed future studies should highlight qualitative studies or mixed methods in support of LA application in Mathematics. Applying a game-based approach (GBL) that has the potential to make the learning process more positive and effective by applying technology is an approach that can be explored in leveraging LA in Mathematics.

Introduction
Today's education has moved forward tracing the 21st century education and towards the 4.0 industrial revolution. The current generation of students needs various techniques and methods of learning in line with students' cognitive development (Nooriza Kassim & Effandi, 2015). This students in this century is a digital generation that is exposed to digital technology applications such as smartphones, iPads, tablets, and so on. They also known as Gen-Z that based on digital-native (Rohaila & Fariza, 2017). The application of this technology has resulted in data that can be utilized by learning analytics (LA) approach.

LA is a systematic process of collecting, analyzing, and reporting the data in depth to describe student learning situations (Ebner, 2014). The LA approach can provide teachers with a clear picture of the progress throughout the teaching and learning process through the analysis of the data obtained from the students (Papamitsiou & Economides, 2014). The ability of the LA approach also allows teachers to anticipate the achievement of student achievement and enable teachers to identify early students at risk in Mathematics learning. This allows teachers to help risky students with intervention programs and thereby prevent pupils from dropping out. This innovation in teaching and learning especially in mathematics will help teacher solve the problem in the classroom (Iksan & Saufian, 2017).

Reports indicate that academics in Europe and the United States apply LA in helping students to succeed in classroom learning (Lu et al. 2017). In 2011, the Horizon Report reported that today's educational trends are beneficial for the future with the application of LA (Johnson et al. 2011) which has the potential to represent the learning process with the benefits of data from technology applications (Ruiperez et al. 2015). Hence, technology and LA applications are very needed by today's teachers because of the burden faced by teachers nowadays become barrier for them to monitor students' behaviour and learning effectively.

Therefore, the researcher conducts a systematic review in viewing the LA application and its benefits to teaching and learning Mathematics. Systematic review allows researchers to perform a clear examination of LA and Mathematics using systematic and explicit methods. As a result, researchers can see the gaps that can be explored and become guides for the future research.

Methodology

This section describes the methods used to find LA related articles in Mathematics. Researcher uses the PRISMA method which includes resources from Scopus and Web of Science that used to run the systematic review, determining eligibility and exclusion criteria, and the systematic review process.

Prisma

The application of PRISMA gives advantages to define clearly the research questions towards systematic research, identifying the selected criteria and being exempted (inclusion and exclusion criteria) in carrying out the review, and helping to get large literature-related data quickly (Sierra-Correa & Cantera Kintz 2015). The application of PRISMA allows the search of terms related to LA and Mathematics. This metadology will ensure that all information relating to LA and Mathematics is acquired in helping to improve the quality of teaching and learning.

Resources

This study is based on two major databases for journals namely Scopus and Web of Science (WoS). The two databases of the journal cover various areas of education such as computers and education, STEM, education and technology, and others. The journals in this database are systematically structured and categorized according to their sources such as paper conferences, journal articles, and chapters in the book.

Eligibility and Exclusion Criteria

Several eligibility and exclusion are specified (see table 1). First selection criteria are the type of literature selected, only journal articles with empirical data selected. This means that review journal articles, book series, chapters in books and conference papers are excluded. Second, selection criteria are an article journal written in English. Journal articles written besides English are excluded. This is to avoid any problems and mistakes in translating and understanding the article journals well. The third is the journal timeline of the selected article between 2009 to 2018. This timeline is an adequate period for the evolution of research and publication (Hayrol et al., 2018) relating to LA and Mathematics.

Table 1 The inclusion and exclusion criteria.

Criteria	**Inclusion**	**Exclusion**
Time Period	2009-2018	<2009
Language	English	Non English
Literature Type	Article (empirical data)	Review article, book, chapter in book, conference proceeding

2.4 Systematic Review Process

There are four stages in the implementation of systematic review. The review process has been implemented at the end of 2018. The first stage is to determine the appropriate keywords to use during the search process. These keywords are identified through past studies and dictionaries, similar keywords related to LA and Mathematics (Table 2). At this stage, after the study was conducted, the same or duplicate journal articles were discarded (n=18).

Table 2 The search string used for the systematic review process

Databases	**Keywords Used**
Scopus	TITLE-ABS-KEY ((*"learning analytics*"* OR *"learning analytic*"*) AND (*"mathematics*"* OR *"math*"* OR *"mathematics education*"* OR *"mathematics educations*"* OR *"math education*"*) AND (*"education*"* OR *"educations*"*))
Web of Science	TS ((*"learning analytics*"* OR *"learning analytic*"*) AND (*"mathematics*"* OR *"math*"* OR *"mathematics education*"* OR *"mathematics educations*"* OR *"math education*"*) AND (*"education*"* OR *"educations*"*))

The second stage was screening. At this stage 155 articles eligible to reviewed, a total of 108 articles were removed. The third stage is eligibility, the full articles were accessed. After careful examination, a total of 17 articles were exclude as some did not focus on search objectives LA and Mathematics. The last rating of the review resulted in a total of 30 journal articles used for analysis (see figure 1).

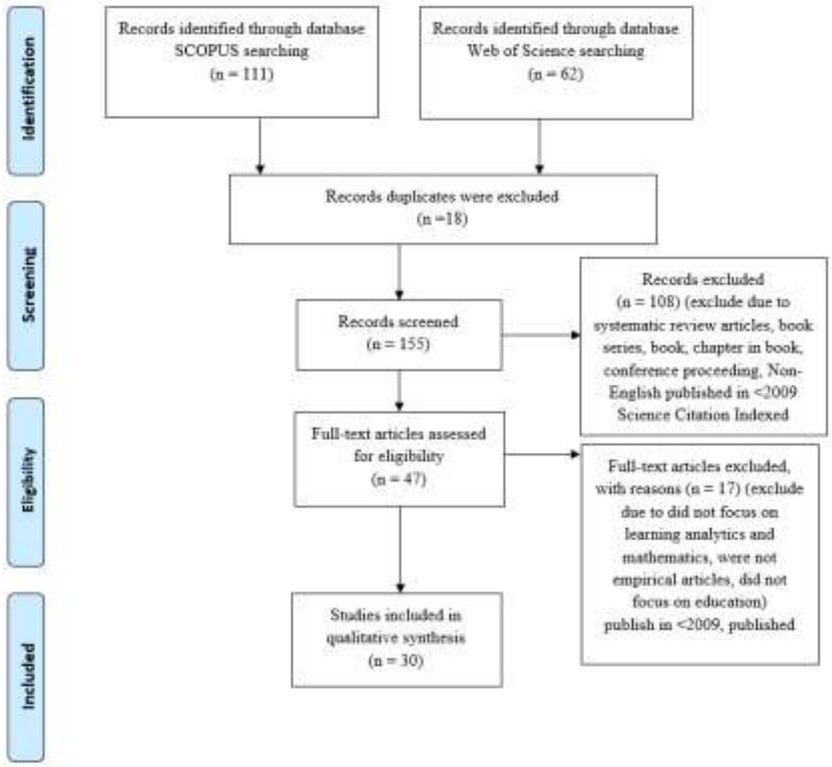

Figure 1 The flow diagram of the study
(Adapted from Moher et al. 2009)

Results

Review of findings show that LA's approach in Mathematics is much applied in improving the quality of the teaching and learning process (Table 3). In this context, the improvement of the quality of teaching through the improvement of the quality of learning materials, the ability to see the development of learning, and the improvement of students' attitude and behaviour towards Mathematics.

Table 3 Learning Analytics Approach in Mathematics

Purpose of Application	Author (Year)
Improve the quality of teaching (n=17)	(Balasooriya et al., 2018; Bertacchini et al., 2018; D. Kim et al., 2018; Gal et al., 2018; John et al., 2018; de Kock & Harskamp, 2016; D. R. Kim et al., 2016; Hue et al., 2015; Kickmeier-Rust, Hillemann, & Albert, 2014; Laakso & Kaila, 2018; Molenaar & Knoop-van Campen, 2018; Quinn et al., 2015; Ruipérez-valiente et al., 2015; San Pedro et al., 2017b; Sivaranjani et al., 2015; Smith et al., 2016; Viswanathan & Vanlehn, 2018)
Make prediction of students (n=12)	(B, Laroussi, & Benghezala, 2015; Cohen, 2017; Dani & Nasser, 2016; Duzhin & Gustafsson, 2018; Roberts et al., 2016; Román-González et al., 2018; Romero-Zaldivar et al., 2012; San Pedro et al., 2017b; Tomkin et al., 2018; Xing, Chen, Stein, & Marcinkowski, 2017b; Xing, Guo, et al., 2015; Xing, Wadholm, et al., 2015)
Students behaviour (n=1)	(Chu, Chen, & Tsai, 2017)

Besides, LA in Mathematics education is also applied in helping teachers make a prediction of student achievement and make student drop out prediction in learning. The ability of LA to give this prediction greatly benefited Mathematics education in helping teachers develop a powerful and effective strategy to avoid dropping out among students and assessing the quality of teaching.

In addition, LA in Mathematics education is often conducted at a higher education centre where it is used to evaluate a Mathematical course. The learning topics are more focused on critical topics such as calculus, statistics, geometry, and STEM. As a result, most studies using case studies in the form of an experimental study.

The review findings also show that most learning settings for LA and Mathematics were in the form of cognitive tutors (special software for study purposes) (see table 4). Some researchers also apply MOOC and LMS learning settings. The application of this learning setting is more focused on the learning process in the university than at school.

Table 4 Learning Setting of LA and Mathematics

Learning Setting	Author (Year)
MOOC	(de Kock & Harskamp, 2016; Hadioui, El Faddouli, Touimi, & Mohammed, 2017; D. Kim, Yoon, Jo, & Branch, 2018; Quinn et al., 2015; Ruipérez-valiente et al., 2015; Xing, Chen, Stein, & Marcinkowski, 2017b)
LMS	(Cohen, 2017; Hue, Kang, & Shin, 2015; San Pedro et al., 2017; Teasley, 2017)
Cognitive tutors	(Chu et al., 2017; Dani & Nasser, 2016; Duzhin & Gustafsson, 2018; Gal et al., 2018; D. R. Kim et al., 2016; Molenaar & Knoop-van Campen, 2018; Román-González et al., 2018; Romero-Zaldivar et al., 2012; San Pedro et al., 2017; Smith et al., 2016; Tomkin et al., 2018; Xing, Guo, et al., 2015; Xing, Wadholm, et al., 2015)
Game Based Learning	(Kickmeier-Rust, Hillemann, & Albert, 2014)

LA in Mathematics

This section will focus on the role LA in Mathematics education such as improving the quality of teaching and learning processes, making prediction in teaching and learning processes, and learning setting applications for LA and Mathematics.

3.1.1 Improving Quality of Teaching and Learning Processes

Previous studies show that seventeen studies apply LA in Mathematics education to help teachers improve the quality of teaching process. In this context, the improvement of the quality of teaching is seen through the improvement of the quality of learning materials, the ability to see the development of learning, and the improvement of student attitudes and behaviors towards Mathematics. Study by Kickmeier-Rust et al. (2014) shows the improvement of game based learning approaches with the application of LA allows researcher to look at the pattern of student engagement. The data show girls are less attracted to the elements of competition than male students. In view of learning progress, Naver Cafe app by Hue et al (2015) helps them to improve student's ability in Mathematics through analyzing data on student engagement activities. The findings of Kim et al. (2016) shows data analysis from the use of Café by students giving information to teachers that the higher the number of student's access to Café, the higher score obtained by the students. This shows that LA application in Mathematics helps improve the quality of teaching with the potential to reflect on student learning progress.

Therefore, it can be concluded that applying LA in Mathematics enables teachers to leverage on the wealth of information in helping teachers provide accurate feedback to students and provide valuable information to teachers in improving the quality of teaching (Siemens, Dawson, & Lynch, 2013) and understand the learning environment more clearly (Siemens & Baker, 2012). The findings of the previous study show LA application helped teachers to understand the progress of students' learning process in Mathematics (Bertacchini et al., 2018, San Pedro et al., 2017, DR Kim et al., 2016; Ruipérez-valiente et al 2015).

However, only one study was reported for the improvement of students' attitude and behaviors towards Mathematics. Chu et al. (2017) shows that LA help leverage the data in understanding student behaviors. The applied peer-tutoring learning approach has led the positive behaviour of students in Mathematics such as increasing the concentration of students in learning activities. As a result, these positive behaviors have helped to improve student learning performance in Mathematics (Chu et al., 2017).

Prediction in Teaching and Learning Processes

Twelve studies reported LA in Mathematics was applied to make predictions of the students. From the reviews, the LA appropriation of predictions is divided into two types, which are predictions of students' achievement and predictions of students' dropouts. The benefits of LA in Mathematics helped teachers predict the achievement of students in Mathematics and predict students who may be dropped through the data obtained (Román-González et al., 2018; Xing et al., 2017; Dani & Nasser, 2016; Romero-Zaldivar et al. 2012).

For these, eight studies have reportedly helped LA in predicting student achievement. A study by Dani and Nasser (2016) reports ALEKS's application helps to measure the achievement of student knowledge and procedural skills and helps students to expect the success of basic Mathematics courses. The data generated from the learning approach had significant correlation with the achievement of students allowing the expectation of student achievement (Romero-Zaldivar et al., 2012). In addition, five studies have reported that LA helps to predict student dropouts. The findings from Cohen (2017) show a change in the pattern of student engagement in learning activities to help risk of students drop out. Application of SAGLET by Schwarz et al. (2018) allows teachers to utilize the data obtained to locate students who are facing problems and have critical situations in learning. The findings from these studies prove that LA in Mathematics help improve the quality of teaching and learning with the potential to help teachers make predictions of achievement and predictions of dropouts among students.

Learning Setting for LA and Mathematics

The review findings also show that most learning settings for LA and Mathematics have largely applied learning settings (Table 4) in the form of cognitive tutors (special software for study purposes). Some other researchers also apply MOOC and LMS learning settings. The application of this learning setting is more focused on the learning process at the university than at the school.

However, the findings of the previous study illustrate that in applying the LA element in Mathematics, a new learning tool needs to be produced. However, there are also previous researchers who only improve existing learning materials by applying LA as a renewal. Table 5 below summarizes the purpose of the study and the categories of learning materials used.

Table 5 Summary of study materials and study purposes

Author (Years)	Learning Materials	Material Category	Purpose	Place
(Romero-Zaldivar et al., 2012)	Cognitive tutors	New	Predict student achievement in the course	University
(Kim et al., 2016)	Cognitive tutors	Upgrade	Improve the quality of teaching	University
(Román-González et al., 2018)	Cognitive tutors	New	Predicting student achievement	University
(Molenaar & Knoop-van Campen, 2018)	Cognitive tutors	Upgrade	Improve the quality of teaching	University
(Tomkin, West, & Herman, 2018)	Cognitive tutors	New	Predicting student achievement	University

Note: Cognitive tutors (special software for study needs)

Review of the previous studies have shown that the construction of new learning by applying the LA used in order to predict the development of students in learning, especially forecasts related to student achievement (Román-González et al. 2018; Tomkin, West, & Herman, 2018; Romero-Zaldivar et al 2012). In addition, LA application also used to improve learning quality (Kim et al., 2016; Tomkin et al., 2018).

Discussion

The LA approach enables teachers to leverage on the wealth of information in helping teachers provide accurate feedback to students and provide valuable information to teachers in improving the quality of teaching (Siemens, Dawson, & Lynch, 2013) and understand the learning environment more clearly (Siemens & Baker, 2012). This is because LA has the potential to provide informative feedback through data analysis which leads to a deep understanding of how learning takes place. This will enable the teacher to identify potential students who are likely to be left out or likely to be assisted by drawing up effective immediate action (Ebner & Schön, 2013) and providing learning interventions to help students (Faridhan et al., 2013). Therefore, the LA application is in line with its goal of interpreting a variety of data about students and predicting learning performance to improve the efficiency and quality of learning. But, it has been found that teacher have deficiency in the usage of technology skills (Ali & Maat, 2019). Hence, technological skill of mathematics teacher like data analysis and LA need to be improved.

In the teaching and learning of mathematics, LA applied to help improve student achievement (Lu et al. 2017) through its ability to provide predictions of student achievement that will earn (Hue et al. 2015). The predictions of the results help teachers take proactive steps to improve pupils' understanding in learning. In addition, the expected results will also encourage students who are at risk of dropping out or who are performing poorly to reverse the learning strategies practiced (Huang & Fang, 2013). It will also enable teachers to review all the teaching methods that have been implemented and the students evaluate the lessons that have been applied whether they are effective. Consequently, the process of teaching and learning will be improved over time to ensure that learning objectives are met, pupils' achievement continues to increase as well as reducing student risk from dropping out.

Past studies show that LA applications in anticipation of student achievement or behaviors require a set of data. Specific variable data types need to be identified by researchers in helping to improve the accuracy of expectations because the data set with variables can increase the correlation value with high precision expectations. However, the addition of many variable data types will not help improve the accuracy of expectations (Huang & Fang, 2013). LA applying in Mathematics also favours doubts about the implementation of a quasi-experimental study especially regarding the existing knowledge of students (Duzhin & Gustafsson, 2018) and describes the experience throughout the student learning process.

5.0 Future Research

Applying LA in Mathematics needs to be explored more deeply as there are many other things that are unclear and known about LA in Mathematics. Therefore, some things need to be addressed. First, most studies apply quantitative research. Hence, future studies should highlight qualitative studies or mixed methods in support of LA application in Mathematics. The application of a quasi-experimental study and LA needs to be explored more profoundly. This is because the application of LA in Mathematics would avoid doubt on the implementation of a quasi-experimental study especially regarding the existing knowledge of the students (Duzhin & Gustafsson, 2018).

In addition, game-based approaches that potentially make the learning process more positive and effective with the application of technology (Okur & Aygenc, 2017; Miller, 2015) is an approach that can be applied in LA and Mathematics. The results showed that only a study was applied by LA and GBL by Kickmeier-Rust et al. (2014). Hence there is still a lack of research that combines the LA approach with GBL, it is highly desirable that the LA and GBL approaches are applied in looking at its effectiveness in helping to improve the mastery of pupils in Mathematics. In addition, future studies should also consider the location of the study. This is because most LA and Mathematics studies are conducted at the university in helping lecturers evaluate the effectiveness of a thinner. Hence, future studies should explore the effectiveness of LA in Mathematics at primary level. This is because school is where the process of learning starts and develop (Bakar, Maat, & Rosli, 2018). Therefore, researchers need to consider using LA in primary school learning. Researchers can also apply various learning settings in evaluating learning settings which are more effective in helping to improve students' mastery in Mathematics. This is due to different learning settings will give students a different learning experience.

Conclusion

This systematic review study emphasizes the importance of applying LA in Mathematics. Among the benefits of LA applying in Mathematics is helping to improve the quality of teaching with the potential to reflect on student learning progress. LA allows teachers to anticipate student achievement and expectation of student dropouts. These expectations allow teachers to identify students who face learning difficulties and further help them improve to prevent dropouts. In future, the application of the LA and GBL approaches in Mathematics is an approach that can be explored in-depth to assess its effectiveness to improve students' mastery in Mathematics. This is because the data from GBL approach can be manipulated to help teachers understand students in deep. Moreover, GBL has the potential to make the learning process more positive and effective especially for students at the lower level. As conclusion, applying LA in Mathematics brings great benefits that will improve the quality of teaching and learning in classrooms. The benefits of GBL should not be disregarded as the combination of GBL and LA can give more positive effect on the process of teaching and learning Mathematics.

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