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Tailored Differentiation in Learning Environment Focusing on Statistics Topics: A Systematic Literature Review

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ABSTRACT : This study explores practical strategies for implementing differentiated instruction (DI), with a particular focus on creating effective learning environments for statistics concepts in mathematics classrooms. By employing the SPAR-4-SLR protocol and TCC framework, this systematic review examined 19 selected articles to identify pedagogical approaches that cater to diverse student needs. The findings indicate that the Statistical Reasoning Learning Environment (SRLE) is extensively used to promote meaningful statistical reasoning. The analysis also highlights self-organized learning environments as a framework with shared characteristics that may support DI in Indonesian mathematics classrooms for teaching statistics. Consequently, this study recommends that SRLE principles be considered by mathematics educators when developing curricula for teaching statistics in schools. However, there are still limited studies in Indonesia, particularly on implementing DI in the classroom and implementing SRLE in differentiated ways for teaching statistics. These insights offer a roadmap for future researchers for possible innovation of emerging SRLE and DI to support students' statistical reasoning.

KEYWORDS – Differentiated instruction, mathematics, statistics, SPAR-4-SLR, TCCM

I. INTRODUCTION

In light of the growing emphasis on diversity, equity, and inclusion within the educational sector, educators are increasingly required to adapt to the diverse needs of their students, which include varying interests, abilities, motivations, and learning profiles [1]. In recent decades, educational institutions have progressively recognized the individuality and diversity of their students [2]. This evolution is primarily attributed to constructivism, the dominant learning theory in contemporary education, and initiatives aimed at ensuring equitable educational opportunities for all learners to learn. Differentiated Instruction (DI) has become a global imperative, functioning as a crucial pedagogical approach to address the complexities of diverse classrooms [3].

In the Indonesian context, the government has promoted the implementation of differentiated instruction [4], motivated by the diversity of students and the aim of Indonesian education. Differentiated instruction (DI) is motivated by the diverse learning needs of students, in line with Indonesian philosopher Kihajar Dewantara, who states that the purpose of education is to: "Guide all the qualities that exist in children so that they can achieve the highest level of safety and well-being as human beings and members of society." DI has been developed as a means of cultivating student diversity [1]. Students increasingly demonstrate a range of backgrounds, such as interests, abilities, motivation, and learning styles [1], [5]. DI is a teaching approach used to proactively recognize and address the diverse characteristics of students by valuing their strengths and adapting teaching methods to support their individual needs and limitations [6], [7]. In other words, DI talks about how different preparing instruction among students, and sees the way students learn based on their preference and personal interest. Thus, it is worth enhancing students' progress by implementing differentiated instruction in the mathematics classroom [8].

In Mathematics classrooms, when we discuss certain concepts that need to be focused on more in a data-driven society, statistics is one of the prior concepts. Every sector of life, such as economics, medicine, and education, experiences a blast of data [9], [10], [11]. This means that individuals, as readers, should be literate in data-based problems. As students enter the workplace, understanding and interpreting statistics becomes essential. All students are expected to leave school as statistically literate citizens [12]. Consequently, it is critical to support high school students in improving their statistical literacy through mathematics lessons. Previous scholars pointed out that developing teaching examples is the central task of mathematics education researchers, that is called as substantial learning environments (SLE) containing four characteristics [13]: (1) representing central objectives, contents, and principles of teaching mathematics at a certain level, (2) related to significant mathematical contents, processes and procedures beyond this level, and so they are rich source of mathematical activities, (3) flexible and easily adaptable to special conditions of a classroom, (and (4) integrating mathematical, psychological, and pedagogical aspects of teaching mathematics, and so it forms a rich field for empirical research. Skovsmove had a similar conceptualization of a substantial learning environment called a landscape of investigation [14]. Van den Heuvel-Panhuizen & Drijvers [15] shared the same similarities concept in the domain specific RME, called learning trajectories. Thus, a learning environment in a mathematical classroom means a teaching unit that consists of several aspects such as (1) a mathematically central goal, (2) rich mathematical activities (contents, processes, and methods) and their assessments, (3) a flexible and adaptable situation, and (4) a mathematical class norm. Studies have shown that DI has been applied in Indonesian mathematics classrooms from elementary [16], junior high school [17], [18], senior high school [19], and higher education [20]. Recent studies have described the effectiveness of applying DI in mathematics classrooms. Jayantika & Santhika [17], Meinur, Yunita, & Gunawan [18], Febriana, Sugiman, & Wijaya [19] reported that students' mathematics achievement increases through differentiated instruction. Students were more motivated and involved during differentiated instruction [21]. Teachers' professional development regarding DI in the mathematics classroom had a positive effect on students' achievement [22].

These studies provide teachers with insight into the effectiveness of DI in supporting and increasing students' mathematics achievement and motivation. However, we need another insight into practical ways of implementing DI in mathematics classrooms. This study addresses the following issues: (1) finding a way to help teachers enact and students attain the Merdeka Curriculum in terms of differentiated instruction (DI) and (2) providing a learning environment for teaching mathematics content in response to statistics topics in senior high schools. Therefore, this study aims to identify the varied approaches used to develop learning environments in the Indonesian mathematics education context. This question is broken down into two sub-questions: (1) What do we know about the literature on learning environments for supporting students learning statistics content? (2) What approaches have been used as the basis for differentiating mathematics instruction in the Indonesian context?

II. LITERATURE REVIEW

Differentiated Instruction: Tomlinson in different publications [6], [7], [23] stated that differentiated instruction is considered as "an approach and as a philosophy of teaching that is based on the premise that students learn best when their teachers accommodate the differences in their readiness levels, interests and learning profiles". In addition, Tomlinson [6], [23] pointed out that "the core of the classroom practice of differentiation is the modification of four curriculum-related elements – content, process, and product – which are based on three categories of student needs and variances – readiness, interest, and learning profile." Fox and Hoffman [24] defined DI as a flexible, equitable, and intelligent approach to teaching and learning. Roy, Guay, and Valois [25] described differentiated instruction as "an approach by which teaching is varied and adapted to match students' abilities using systematic procedures for academic progress monitoring and data-based decision-making" Each of these definitions stresses that DI is considered as a teaching approach used to proactively organize teaching and learning experiences in order to address the diverse educational needs of students in heterogeneous classrooms using a wide range of instructional methods.

Tomlinson [6] identifies three fundamental components in the implementation of Differentiated Instruction (DI). The first component, content, pertains to the educational objectives set by the teacher, typically aligned with the school's curriculum. In differentiating content, educators meticulously select instructional materials and resources, which may encompass a variety of genres, materials at different levels, diverse instructional tools, and options for students to choose from. The second component, process, encompasses activities designed to facilitate students' comprehension of essential information, concepts, and ideas. These activities are customized to align with students' readiness levels, interests, and learning profiles. The third component, product, involves a culminating project that students develop to demonstrate and extend their learning by the conclusion of a unit of study. The creation of a product can be particularly empowering for students, as it necessitates critical and creative thinking, the application of knowledge, and the enhancement of their understanding and skills. Differentiated instructional strategies can be performed in two forms: tiered assessment and flexible grouping. Tiered assignments are constructed according to student readiness level, build on prior knowledge and are at varying levels of difficulty while the instructional concept remains the same [23]. With the use of tiered assignments, students are less likely to be over-challenged or bored with an assignment, thereby promoting student learning. Meanwhile, flexible grouping allows teachers to meet student needs and build on big ideas or concepts introduced in whole group format [23]. teachers can group students according to the following, "information sources available, tasks, student interests, skill or ability level of students, learning styles and multiple intelligences, thinking skills and process or product desired" [6].

Learning Environment: Wilson [26] defines a 'constructivist' learning environment as a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem-solving activities. Wittmann [13] pointed out that developing teaching examples is the central task of mathematics education researchers. Later, it was called substantial learning environments (SLE), which have the following characteristics:
It represents the central objectives, content, and principles of teaching mathematics at a certain level.

a. It is related to significant mathematical contents, processes and procedures beyond this level, and so they are rich source of mathematical activities
b. It is flexible and easily adaptable to special conditions of a classroom
c. It integrates the mathematical, psychological, and pedagogical aspects of teaching mathematics, forming a rich field for empirical research.

Gravemeijer [27], shared the same similarities concept in the domain specific RME, called learning trajectories. Clement and Sarama [28] described learning trajectories as conjectures, based on an empirical study of student learning and of how student ideas develop from conceptions to learned ideas (domain goal understandings) in which classroom instruction is assumed to play a central role, including all forms of teacher support, appropriate tasks and tools, peer-to-peer discourse, and the language necessary to specify and build ideas. In this study, a learning environment in a mathematical classroom means a teaching unit that consists of several aspects such as (1) mathematical central goal, (2) rich mathematical activities and their assessments, (3) flexible and adaptable situations, and (4) mathematical class norms. The use of the metaphor of an environment emphasizes that all aspects are one entity.

III. METHODOLOGY

This study employed a systematic literature review (SLR) as a valid methodology [29] to synthesize a collection of research articles that fit the criteria for inclusion regarding the research questions [30]. The procedure was used to ensure a transparent and reproducible process, called the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol, consisting of three main phases: assembling, arranging, and assessing, and six sub-stages [31]. The protocol begins with the assembling phase, which includes identification for defining search strings and acquisition for gathering raw literature. In the identification sub-phase, the learning environment in mathematics education was identified as the domain from typical sources such as peer-reviewed articles in Scopus and Google Scholar. To gather the literature review in the acquisition sub-phase, we utilized Publish and Perish software with a limitation period from 2000 to 2024. The search keywords included learning environment, statistical literacy, statistical reasoning, differentiated learning, and mathematics. The total number of articles from the search mechanism was 1,568; Scopus accounted for 137 and Google Scholar for 1,431.

The phase is followed by the Arranging phase, where researchers perform Organization to clean data and remove duplicates and Purification to apply strict inclusion/exclusion criteria to filter the results (Table 1). In the organization sub-phase, we removed duplicates by employing the theory, context, characteristics, and method (TCCM) framework [32]. We then implemented some codes: the theoretical foundations, context, that is country and learning environment type in the mathematics classroom, character, that is learning environment related to statistical reasoning and varied approaches in differentiated instruction, methodology, that is sample and analysis. In the next sub-phase, we excluded 1,444 articles after screening the titles and abstracts that were not related to mathematics instruction, and 105 duplicate articles using Ms. Excel. As a result, we obtained 19 articles (Table 2). Finally, the Assessing phase involves Evaluation for critiquing the quality of the remaining articles and Reporting for extracting data to create new insights, effectively transforming a massive collection of documents into a refined scholarly contribution. In the Evaluation sub-phase, we generally used the TCCM method. However, this study only focuses on the elaboration of the TCC method. In the final sub-phase, we described the data using tables and figures. The data were subsequently analyzed qualitatively to emphasize their meaning.

Table 1. Purification sub-phase criteria

Process on sub-phase	Description
Inclusion	• The scope related to statistical reasoning learning environment and/or differentiated learning in mathematics education • Full papers of Proceedings of International Conference from the last ten years
Exclusion	• Non-English written studies • Books, report, thesis/dissertation

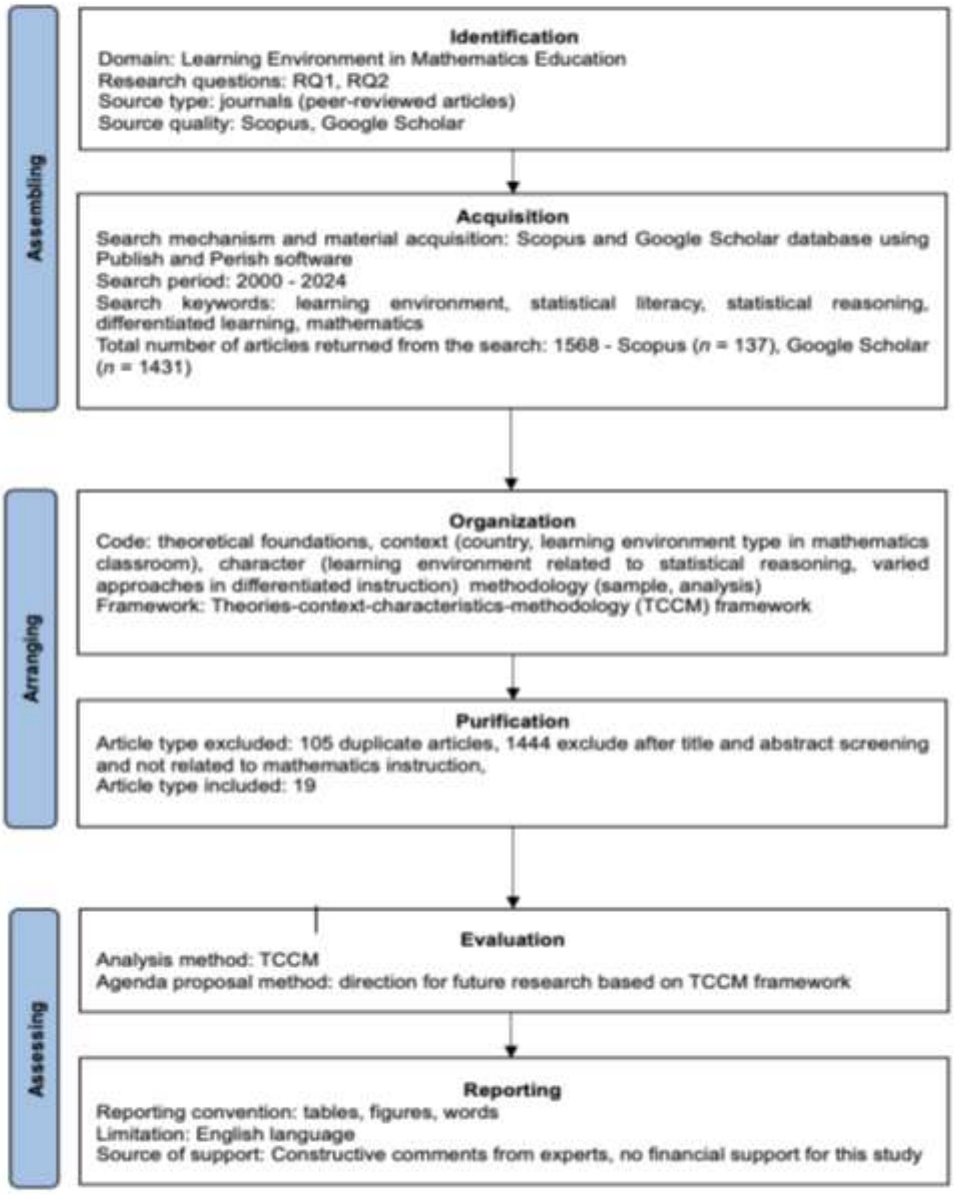

Figure 1. Flowchart of SPAR-4-SLR protocol in this study

Table 2. Article included in review

No	Authors	Title	Year	Source	Cites
1	Insorio, A. O., & Librada, A. R. P.	Differentiated Instruction in Mathematics Classes: Increasing Student's Mathematics Performance and Engagement in Statistics and Probability	2024	Puissant	0
2	Ben-Zvi, D.	Statistical reasoning learning environment	2011	EM TEIA| Revista de Educação Matemática e Tecnológica Iberoamericana	50
3	Poelmans, S., & Wessa, P.	A constructivist approach in a blended e-learning environment for statistics	2015	Interactive Learning Environments	59
4	van Dijke-Droogers, M., Drijvers, P., & Tolboom, J.	Enhancing statistical literacy	2017	CERME 10	11

No	Authors	Title	Year	Source	Cites
5	Faber, J. M., Glas, C. A., & Visscher, A. J.	Differentiated instruction in a data-based decision-making context	2018	School effectiveness and school improvement	145
6	Simanjuntak, L. N., Yantoro, Y., Radmika, H. A., & Basyir, B	Increasing student activeness using the TaRL approach through differentiated learning on statistics material	2024	Journal of Mathematics Education	4
7	Songer, N. B., Newstadt, M. R., Lucchesi, K., & Ram, P.	Navigated learning: An approach for differentiated classroom instruction built on learning science and data science foundations.	2020	Human Behavior and Emerging Technologies	22
8	Garfield, J., & Ben-Zvi, D	Helping students develop statistical reasoning: Implementing a statistical reasoning learning environment	2009	Teaching Statistics	242
9	Conway IV, B., Gary Martin, W., Strutchens, M., Kraska, M., & Huang, H.	The Statistical Reasoning Learning Environment: A Comparison of Students' Statistical Reasoning Ability	2019	Journal of Statistics Education	38
10	Burckhardt, P., Nugent, R., & Genovese, C. R.	Teaching Statistical Concepts and Modern Data Analysis With a Computing-Integrated Learning Environment	2021	Journal of Statistics and Data Science Education	37
11	Showalter, D. A.	Attitudinal changes in face-to-face and online statistical reasoning learning environments	2021	Journal of Pedagogical Research	12
12	Wei Chan, S., Ismail, Z., & Sumintono, B	The impact of statistical reasoning learning environment: A rasch analysis	2015	Advanced Science Letters	17
13	Wei Chan, S., Ismail, Z., Sumintono, B, Omar, S. S., & Ramlan, R.	The effects of statistical reasoning learning environment in developing secondary student's statistical reasoning	2017	Journal of Engineering and Applied Sciences	0
14	Ben-Zvi, D., Gravemeijer, K., & Ainley, J.	Design of statistics learning environments	2018	International handbook of research in statistics education	128
15	Madden, S.	Designing technology-rich learning environments for secondary teachers to explore and prepare to teach statistics	2014	Sustainability in Statistics Education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9)	8
16	Olgun, B., & Akyüz, D.	The development of pre-service teachers' informal inferential reasoning: A case of a statistical reasoning learning environment	2023	Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13)	0
17	Bakker, A., & Van Eerde, D.	An introduction to design-based research with an example from statistics education	2014	Approaches to qualitative research in mathematics education: Examples of methodology and methods	599
18	Rahmawati, N. P., Asikin, M., & Scolastika, M.	Analysis of Students' Statistical Literacy on Self Organized Learning Environment (SOLE) Learning Model	2022	Mathematics Education Journal	5

IV. RESULTS AND DISCUSSIONS

What do we know about the literature on learning environment for supporting students learn statistics content?

We explored the literature on learning environment for supporting students in learning statistics based on TCC method as follows.

***Theoretical foundation* (T)**

We examined the theoretical foundations of learning environment in mathematics classroom, particularly for learning statistics are presented as follows.

Table 3. Learning environment for Statistics topic by previous studies

Type of Learning Environment	Number articles	Exemplary
Statistical Reasoning Learning Environment	8	2, 8, 9, 11, 12, 13, 14, 16
e-Learning Environment	5	3, 10, 15, 7, 17
Self-Organized Learning Environment	1	18

Table 3 pictured the statistical reasoning learning environment (SRLE) has been widely applied to teach statistics; counted 8 of 19 articles. The SRLE is an encouraging statistics classroom that helps students gain a meaningful and profound comprehension of statistics as well as the capacity to reason and think statistically [33, 34]. Meanwhile, the other researchers utilized digitalized learning environment and self-organized learning environment to support students in learning statistics.

***Context* (C)**

The learning environment within mathematics classrooms, particularly in relation to statistical topics, is integral to the context in which these studies have been conducted.

Table 4. The context of articles

Country	Number articles	Exemplary
Belgium	1	3
The Netherlands	3	4, 5, 17
Turky	1	16
US	5	7, 9, 10, 11,15
Malaysia	2	12, 13
Indonesia	2	6, 18
Philippines	1	1

Although not every article explicitly states the country context of their research, we can still grasp the overall picture. The distribution of the three groups of countries according to the implementation of SRLE is as follows: Asia (Malaysia, Indonesia, and Philippines), Europe (the Netherlands, Belgium, and Turkey), and the US. This result shows that the research has already been concerned in Indonesian education context.

***Characteristics* (C)**

To understand the nature of the learning environment in mathematics classrooms, especially for teaching statistics, we can examine the pedagogical methods employed, as shown in the table

.

Table 5. The characteristics of articles related learning environments

Characteristics	Number articles	Exemplary
Differentiated instruction	5	1, 4, 5, 6, 7
Constructivist	5	8, 9, 14, 16
Self-organized learning	1	18

Out of the 19 mentioned, only 10 explicitly detailed the approach they employed. The methods that share common traits in focusing on defining learning objectives, identifying students' educational needs, and involving learning activities include differentiated instruction, constructivism, and self-organization.

What approaches have been used as the basis of differentiating mathematics instruction in Indonesian context, particularly for learning statistics?

The Indonesian government has emphasized that differentiated instruction (DI) is a teaching method that adapts to the needs of all learners, aligning with Tomlinson's principles. This approach adjusts based on students' readiness, interests, and learning profiles, including their strengths and challenges. Teachers can differentiate in terms of content, process, and product. From the SLR, we observed that the DI approach (C) and the learning environment (T) of SRLE, as shown in tables 5 and 3, do not overlap in any articles. This indicates an opportunity for future research to delve into this area. Specifically, there is potential for further exploration in mathematics education to teach statistics by simultaneously employing SRLE and DI.

The six principles of SRLE are key elements in developing a class in which students are engaged in making and testing conjectures using data, discussing and explaining statistical reasoning, and focusing on the important big ideas of statistics.

a. Focus on developing central statistical ideas rather than presenting a set of tools and procedures.
b. Use real and motivating data sets to engage students in making and testing conjectures [35].
c. Use classroom activities to support the development of students' reasoning.
d. Integrate the use of appropriate technological tools that allow students to test their conjectures, explore and analyze data, and develop their statistical reasoning [36], [37].
e. Promote classroom discourse that includes statistical arguments and sustained exchanges that focus on significant statistical ideas.
f. Use alternative assessment.

Another possible method that shares characteristics in addressing students' varied learning needs is known as the open learning environment (OLE) and self-organized learning environment (SOLE). According to Hannafin, Land, and Oliver [38], OLE focuses on setting learning objectives, identifying students' learning requirements, and participating in educational activities. They also noted that OLE encourages students to expand their thinking through a range of learning tools, resources, activities, and teacher support. These varied elements motivate students to formulate problems. Specifically, [39] introduced a concept akin to the open-ended problems approach used in Japanese mathematics education. He clarified that this method aims to promote diverse student activities and enhance their mathematical reasoning. The term "open" pertains to both students and mathematical activities simultaneously.

V. CONCLUSION

This research highlights the importance of shifting towards learning environments that are both structured and flexible to effectively implement differentiated instruction (DI) in school statistics. Through a systematic review using the SPAR-4-SLR protocol and TCC framework, the study identifies the Statistical Reasoning Learning Environment (SRLE) as an ideal model for promoting deep statistical reasoning. The results suggest that the common characteristics of self-organized learning environments offer a promising model for Indonesia. Therefore, the study advises mathematics educators to consider SRLE principles when designing curricula for teaching statistics in schools. However, there is a scarcity of studies in Indonesia, particularly regarding the classroom implementation of DI and the application of SRLE in differentiated ways for teaching statistics. These findings provide a guide for future researchers to potentially innovate emerging SRLE and DI to enhance students' statistical reasoning. Ultimately, adopting these scalable educational frameworks will ensure that mathematics teaching remains responsive to the diverse needs of students, thereby improving both achievement and motivation within the national education system.

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