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DATA-DRIVEN DIFFERENTIATION

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Abstract

The heterogeneous classrooms of today require teachers to differentiate effectively. Effective differentiation however is a very time-consuming process. Teachers are faced with the challenge of first identifying the students in need of differentiated content, be it in the form of more support and easier exercises for struggling students or more challenges for high-performing students. Once these needs are identified, the teacher still needs to come up with the differentiated material that best suits the needs of each student. The identifying of differentiation needs and the delivery of differentiated content should preferably happen as the need arises, not as a delayed reaction based on observations from an exam for example. This trifecta of identifying needs, providing suitable content, and doing it all at the right time is what makes differentiation so difficult. In this article, we present a study where a digital learning platform called Eduten was used to provide automated suggestions for differentiation to teachers. The participants (N=757) were divided into two groups based on whether the teacher followed the suggestions or not. According to results, the differentiated students increased their accuracy significantly, while in the other group the accuracy remained the same. The number of completed exercises also increased more in the differentiated group, suggesting a raise in motivation. Based on the results, automated suggestions for differentiation can be highly useful but only, if the teacher follows them.

Keywords: *Differentiation, learning analytics, digital learning, technology, data-driven.*

1. Introduction

Vygotsky's Zone of Proximal Development (ZPD) is a theory commonly applied to help us understand how people learn. The fundamental idea behind ZPD is that students have an optimal zone when learning new concepts, where the task at hand is neither too easy nor too difficult. With support from a more experienced person, typically a teacher, a student can expand this "zone" and work on tasks outside of their own level. With time, the student will learn and be able to do this work without the added support. (Vygotsky, 1978) Kurvinen (2020) explains how technology enhanced learning (TEL) can help ensure that students are kept in their ZPD and provided with the needed support through differentiated exercises while working in a digital learning environment. The need for differentiation is evident in the heterogeneous classrooms of today (Asim, 2020; Tomlinson, 2014).

While differentiation can be traditionally be seen as a difficult and tedious process, according to Kurvinen (2020) technology can make the process easier. Tomlinson (2014, p. 17) states that formative assessment provides teachers of differentiated classrooms with a steady stream of information about how their students are performing. This in turn helps the teacher to understand how they should modify upcoming instruction to better suit the needs of their students. With TEL, we have the ability to gather formative assessment data about students as they are working and analyze that data through the process of learning analytics. This data can be used to provide teachers with recommendations for differentiation.

Some studies (Burns, 2012; Haelermans, 2013, 2015;) seem to suggest that differentiation with digital online tools can have positive effects on learning outcomes and that technology is especially suited for differentiation (Haelermans, 2015). Furthermore, several studies suggest that digital learning tools can have a positive effect on mathematics learning outcomes (Cheung & Slavin, 2013; Pilli & Aksu, 2013; Laakso, 2018; Kurvinen, 2020). Similar to Haelermans (2015), we found that the field of study looking at how using digital technology for differentiation affects learning outcomes is still quite limited, furthermore in the context of mathematics.).

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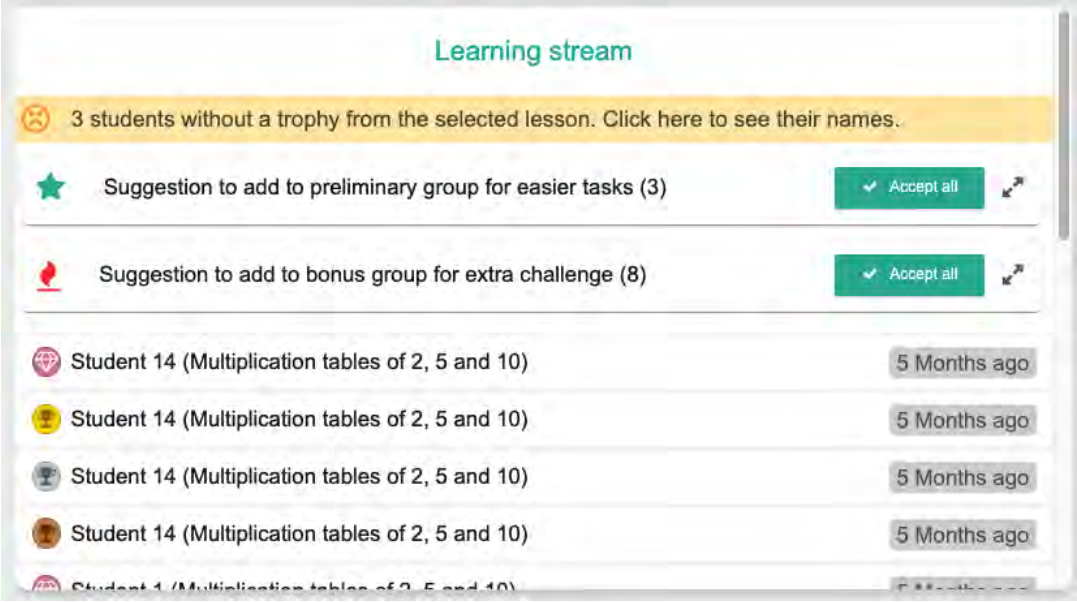
2. Eduten

Eduten is a gamified, digital platform with a focus on mathematics education. It contains several different exercise types ranging from traditional math exercises (such as multiplication tables or long division) and math games to versatile and more complex problem-solving exercises. All exercises are automatically assessed and provide immediate feedback. Randomized parameterization means that students can answer the exercises immediately again if they fail at the solution. There is existing content for K-12 teaching supporting different curricula around the world. In total, Eduten contains more than 19 000 different exercises. For teachers, the system provides multifaceted learning analytics to help in tracking student progress and reveal potential problems in learning. A comprehensive description of the platform can be found in Kurvinen (2020).

For this study, a new mechanism supporting differentiation was designed and implemented. The mechanism uses automated learning analytics to detect students who might benefit from the easier or more difficult tasks. Instead of differentiating students automatically, the system provides the responsible teacher suggestions for this. Hence, the teacher is the one making the final decision, as suggested by Asim (2020). An example of such a suggestion is provided in Figure 1.

Figure 1. Suggestion for Differentiation presented on the teacher dashboard in Eduten.



The content in Eduten is divided into *courses* which are further divided into individual *lessons*. Each lesson consists of 20 to 40 exercises. Differentiating for students in demand of easier tasks means that the students are provided easier exercises (also referred to as *warm-up exercises*) which are designed to prepare them for the lessons' standard content. By completing the exercises the students collect virtual trophies. A bronze trophy is awarded when 50% of tasks is completed, a silver trophy for 75% percent, a gold trophy for 90% percent and finally a diamond trophy for completing 100% percent of all available points. Students can decide by themselves which exercises to complete and in which order. Even the differentiated exercises are not forced on students.

3. Method

In this paper, we compare results from students who were differentiated with easier tasks by the teacher to those students to whom the platform suggested to be differentiated with easier tasks but the suggestion was not applied by the teacher. The data was gathered automatically by the students using Eduten. The following criteria was applied when filtering for the data:

- The student account must have been created before January 1st, 2022.
- The differentiation decision must have been made or the differentiation suggestion given in February
- The data collected during January 2022 was used as pre-treatment data.
- The data collected during March 2022 was used as post-treatment data.

The user interface for suggestion was redesigned mid December 2021. Hence, we selected data from early 2022 to only include suggestions after the redesign. We analyzed the data from students who used the platform both in January and March. A total number of 757 students were included (N=757). This sample represents all the students in the system who fulfill the above requirements for the data. The students range from 1st grade to 9th grade (6 to 15 year olds, depending on the country and curriculum). The students were divided into two groups based on the differentiation status in the system: out of the 757 students, 331 were differentiated and 426 students were suggested to be differentiated but the differentiation was not applied. In the usage data we observed the average accuracy of students' answers and number of submitted answers: accuracy was calculated by dividing the number of correct answers with the number of total answers. The research setup is displayed in Figure 2.

Figure 2. Research setup.

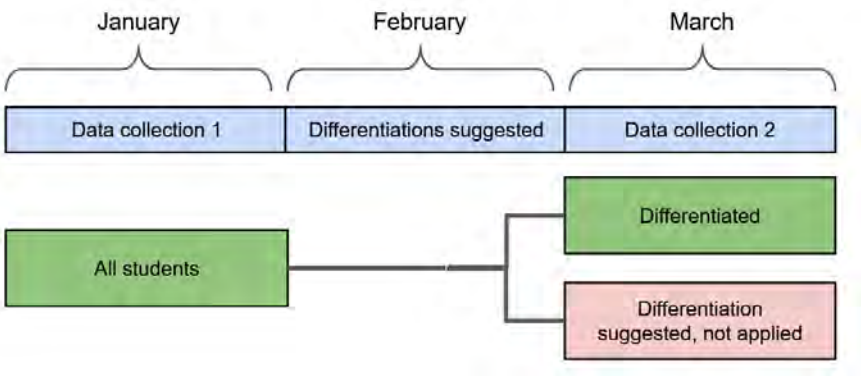


Table 1 describes how the students fulfilling the criteria are distributed in different grade levels. 95.1% of the differentiated students are in grade levels 2-6. The respective value for suggested, not applied students is 88.7%, hence the students are slightly more spread out within the latter category.

Table 1. Distribution of differentiated students and suggested, not applied students along grade levels.

	Differentiated		**Suggested, not applied**	
Grade level	**N**	**%**	**N**	**%**
1	9	2.31%	23	4.78%
2	68	17.48%	52	10.83%
3	76	19.59%	123	25.68%
4	90	23.26%	75	15.69%
5	62	16.06%	100	20.96%
6	72	18.70%	74	15.55%
7	7	1.82%	25	5.26%
8	3	0.78%	5	1.05%
9	3	0.79%	4	0.85%

The grade levels are defined by the content used by the students, not their actual age. The school age varies from country to country and the grade level is considered as a suitable way to compare the similarity of these two groups.

4. Results

Accuracy for the both groups was calculated in two points: first in January (before the decisions for differentiation) and second in March (after the decisions). Median and mean accuracy and the standard deviation was calculated for both groups, respectively. In addition, a difference between January and March points was calculated. In addition to accuracy, number of submissions during January and during March was calculated. The results are displayed in Table 2.

Table 2. Student activity and accuracy data before and after differentiation decision or non-applied suggestion.

		Differentiated		Suggested, not applied	
		Accuracy	**Submissions**	**Accuracy**	**Submissions**
January	**Median**	81.68%	58.00	79.40%	62.00
	Mean	80.81%	83.10	77.27%	77.60
	St. dev.	12.16%	84.89	13.52%	66.11
March	**Median**	87.93%	76.00	81.19%	64.00
	Mean	86.11%	90.62	78.43%	92.82
	St. dev.	9.71%	76.92	14.58%	96.92
Difference	**Median**	4.63%	11.00	0.48%	5.00
	Mean	5.30%	7.45	1.21%	15.17
	St. dev.	13.03%	85.15	15.88%	91.30

The *difference* row displays the calculated difference for each student from January to March. A two-tailed T-test was used to find out if there were statistical differences in accuracy between January and March data. For differentiated student, the difference was statistically significant ($p < .001$). For the suggested, not applied group, the difference was not statistically significant ($p = 0.13$, $p > 0.05$).

The mean difference in submissions between the two groups indicates slightly higher activity for the differentiated group, but is should be noted that the standard deviation is quite large in both groups.

5. Discussion

The results clearly show that the accuracy of differentiated students increases statistically significantly, while the accuracy for the group with non-applied suggestion remains on an earlier level. This is understandable due the fact differentiated students will receive tasks which are more suitable for their skill levels. Moreover, the data suggests that the number of submissions made by differentiated students increases more, which can be seen as a sign of improved motivation. Getting a sense of success being encouraged is one way of relieving math anxiety (Ashcraft, 2002). The results presented here are promising and indicate that differentiation using digital technology can provide benefits for learning outcomes, a similar finding to that of Haelermans (2013, 2015). The difference with this study in comparison to e.g. Haleremans (2015) is the use of learning analytics instead of tests to automatically identify differentiation needs and make suggestions for teachers.

We propose that further investigation is needed on how learning analytics could provide a steady stream of information to help the teacher better understand how their students are performing, similar to information provided by formative assessment in Tomlinson's (2014) examples of a differentiated classroom, and how this information could be used for more effective differentiation by the teacher. The high standard deviation suggests a lot of variation in both of these groups. On average, differentiation is able to create a more positive learning experience and outcomes but on an individual level one can observe different results.

For future research, it is important to try to identify which students benefit most from differentiation and if there is a way to improve the effectiveness of differentiation for the students who did not seem to benefit from it at the moment. Another interesting aspect is to observe possible differences in effectiveness of differentiation between grade levels. Finally, the third direction for future research would be to find out if providing more challenging tasks to more skilled or faster students would be beneficial to their learning or motivation.

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