Underperforming schools in the Kingdom of Saudi Arabia
Clustering analysis using TIMSS 2019 Microdata

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ABSTRACT: This paper aims to identify disadvantaged groups of schools in the Kingdom of Saudi Arabia and offer tailored recommendations to improve these schools' performance. The empirical analyses conducted in this paper are based on the 8th-grader's microdata from the Trends in International Mathematics and Science Study (TIMSS 2019). To identify groups of schools with homogenous characteristics, we used *k-means clustering* and latent profile (for the sake of robustness checks). Statistical grouping allowed us to identify sub-groups of schools and latent patterns of their performance. After identifying the main differences between school clusters, the weighted *regressions* on their mathematics and science achievements were performed using the explanatory variables describing the school, teacher, and student characteristics. Results show that the low-performing cluster is, on average, around 150 points below the top-performing one (which performs close to the international average), which means that students from the disadvantaged cluster are far behind basic curriculum requirements. Those schools differ fundamentally concerning student and school resources, environment, teaching method, and teachers' characteristics. The data show that support for students in these schools is indispensable, including providing them with access to appropriate educational materials they cannot access at home.

Keywords: MENA, School Profile, K-means clustering, Education Improvement, TIMSS, ILSAs, School Reform.

المستخلص: تهدف هذه الورقة لتحديد فئات المدارس الأقل أداء في المملكة العربية السعودية وتقديم توصيات مخصصة لتحسين أداء هذه المدارس. تستند التحليلات التجريبية التي أجريت في هذه الورقة إلى البيانات التفصيلية للصف الثامن في الدراسة الدولية لاتجاهات الرياضيات والعلوم .(TIMSS 2019) لتحديد مجموعات المدارس ذات الخصائص المتجانسة ، استخدامت مجموعة خوارزميات التجميع kوالملف الشخصي (البروفايل) الكامن، والتي أمكن من خلالها تحديد مجموعات فرعية من المدارس والأنماط الكامنة لأدائها. بعد تحديد الاختلافات الرئيسية بين مجموعات المدارس ، تم إجراء الانحدارات المرجحة على التحصيل الدراسي في الرياضيات والعلوم باستخدام المتغيرات التوضيحية التي تصف خصائص المدرسة والمعلم والطالب. وتظهر النتائج أن مجموعة المدارس ذات الأداء المنخفض هي في المتوسط أقل بحوالي 150 نقطة من مجموعة المدارس الأفضل أداءً (والتي تقترب من المتوسط الدولي) ، مما يعني أن الطلاب المدارس الأقل أداء متأخرون كثيرًا عن متطلبات المناهج الأساسية. وتختلف هذه المدارس بشكل أساسي فيما يتعلق بموارد الطلاب والمدرسة والبيئة وطريقة التدريس وخصائص المعلمين. وتُظهر البيانات أنه لا غنى عن دعم الطلاب في هذه المدارس ، بما يمكنهم من الوصول إلى المواد التعليمية المناسبة التي يفتقرون لها في المنزل.

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Introduction

Studies show that we can position schools on a spectrum of cumulatively advantaged to disadvantaged (Thrupp & Lupton 2011; Poesen-Vandeputte & Nicaise, 2015). In the literature, attention is paid primarily to the latter (Lupton & Thrupp, 2012). Depending on the position of schools, their needs are different and require diverse responses. Often it is not possible to create one universal policy, since this would discriminate against certain groups. Clustering schools into homogeneous groups allows us to evaluate problems more accurately, the proper allocation of resources, and better response to specific needs. Policy and treatments can be based on a better understanding of the school groups: instead of one, several solutions can be proposed and tailored to the respective clusters.

Certainly, all schools are guided by common goals - to provide high-quality education, prepare students for life in society and facilitate their entry into the labor market. Sharing the same goals, why do some schools perform better than others? Are they more effective, or are there other factors behind this? School context is made up of different kinds of resources. Firstly, schools can differ strongly in terms of school population and student-level characteristics. The literature most often emphasizes the differentiation of schools due to the socioeconomic or ethnic characteristics of students (Reardon, Yun & Kurlaender, 2006; Colman, 1968, Agirdag, Loobuyck & Van Houtte, 2011; Corcoran & Jennings, 2018). These differences are often compounded by the division of schools into public and private. In some countries poverty and ethnicity are correlated and ethnic minority students are more likely to attend poor schools. As socioeconomic status is a one of the main predictors of achievement (Palardy, 2013; Owens, Reardon & Jencks, 2016), usually the proportion of disadvantaged students is in line with the school's performance. Students from poorer backgrounds make smaller progress compared to others (OECD, 2011). The impact of socioeconomic status on education is explained by role models, different values, beliefs, expectations of further education and life, as well as the level of parents' expectations; all these features may be reflected in attitudes towards education (Palardy, Rumberger & Butler, 2015). The status-based self-selection of student can even widen the inequalities and worsen opportunities for the most disadvantaged, leading to lower aspirations and participation rates in later education (Schmidt, Burroughs, Zoido, & Houang, 2015). Also, well-off students attend well-equipped schools more often. Phillips & Chin (2004) noted that schools serving low-income populations usually offer fewer instructional resources, less experienced teaching staff and a less demanding or rigorous curriculum, which may explain the lower scores of their students. Teachers employed in disadvantaged schools also have lower expectations of their student's achievement, which Warren (2002) observed in poor urban schools. It is worth adding that teachers' expectations disproportionately affect poor students' performance (Sorhagen, 2013; De Boer, Timmermans & Van Der Werf, 2018). The literature suggests that the most educationally oriented parents and students and well-qualified teachers gravitate towards schools with better facilities and technology. Both groups are guided by an interest in their own good and strive to maximize their satisfaction. Research shows that teachers are even willing to commute further to a place of work if it offers them better conditions, instructional resources, and teaching materials. Regarding teachers, studies indicate that disadvantaged schools have higher teacher turnover and higher percentages of novice teachers, which lowers students' educational results. We see that good schools simply accumulate resources.

School differences may partly result from inequalities in school districts' financial resources. We may deal with regional differences, providing children with unequal opportunities for educational success, such as a safe environment and school facilities. With the distinction between rural and metropolitan schools also comes the distinction between the advantaged and disadvantaged areas within countries. Lupton (2004) underlines the point that because of this educational policies should be contextualized to local circumstances.

Apart from socioeconomic and ethnic composition, we can also observe segregation by previous academic performance. More selective schools may perform better not because they provide better services but because they simply do not accept poorly-performing students (Hind & Pennell, 2007). The effect is stronger when pupils are sorted into different tracks by ability (West, Hind & Pennell, 2004; Danhier, 2018).

Study problem

The historical trends in Saudi students' performance show that the country's educational system faces significant challenges, as scores obtained in the TIMSS assessment are below the international average and do not show consistent signs of improvement (Mullis, Martin, Foy, Kelly & Fishbein, 2020). This can generate significant losses, not only for students but also for the development of the country, as it has been demonstrated that a better educational performance can improve economic growth and development in the medium- to long-run (Hanushek & Woessman, 2010). Thus, it is important to correctly evaluate the most urgent interventions that could be made to improve the educational performance of students, and especially so in the most disadvantaged schools.

This paper aims to fill the gap in defining tailored recommendations for the disadvantaged school cluster. Implementing targeted policies requires first the clear identification of vulnerable schools. This process can be done using many different methods. In this paper, we used both k-means clustering and latent profile models using the microdata from the TIMSS 2019 assessment. Statistical grouping allowed us to identify similar schools based on predefined characteristics. In this way, the group of schools that need the most help can be identified. Finally, the most disadvantaged schools were described in terms of their statistical characteristics. Based on this evidence, the most effective measures for the improvement their situation are proposed.

Governing Saudi Schools and policies for school performance

Ministry of Education (MOE) in Saudi Arabia centrally manages 38,000 schools, half a million teachers, and six million students through 47 education directorates and nearly 250 educational offices (MOE, 2020). Though the daily operations at schools are delegated to school principals, the MOE is responsible for setting educational policies and curricula, allocating financial resources, hiring staff, selecting and/or approving textbooks, and maintaining the education system (Meemar, 2014). In this daunting task, the MOE conducts it activities through supervision departments, with nearly 10,000 supervisors at the central level, and through educational directorates. Supervisors basically ensure the compliance of schools, and support them professionally and administratively. During the last two decades there has been a trend in K-12 reforms in Saudi Arabia that led through other governmental bodies than MOE, aiming for more governance and accountability of reform initiatives.

Among these reforms was the King Abdullah Project for the Development of Public Education, " Tatweer," was initiated in 2007 by King Abdullah (1924-2015) and subsidized with a seven-year budget, the largest ever, at $2.4 billion (Tayan, 2017) aming for decentralization of the educational process administration and granting of more autonomy to educational offices and schools.

Six years later the Public Education Evaluation Commission (PEEC) was established to become a fully independent authority from the Ministry of Education. Besides evaluating schools, and building qualifications for educators, it was charged with administering the International Large Scale Assessment (ILSAs) studies such as TIMSS, PIRLS, and PISA (ETEC, 2022) .

In 2020, the Human Capacity Development Program (HCDP) was launched. This is one of the most prominent institutional reform megaprojects ever (Saudi Vision 2030), that focuses on developing a solid educational base for all citizens (Vision 2030, 2022). Among its 16 objectives is improving fundamental learning outcomes, with specific s indicators mostly related to ILSAs and expecting about an (4-8 SD) increase in student scores. By 2025, for example, it expects 8th-grade students to score 484 (484/2019) in mathematics, and 493 (402/2019) in science.

Despite the ambitious aspirations of these initiatives, the historical data for participation in these assessments since 2003 (Mullis, Martin, Foy, Kelly & Fishbein, 2020) indicates that there is much to be done. However, with the tremendous commitment of government to address the increased demands of education, more effective policies should be tailored to the local context and continuously evaluated.

School achievement in Saudi Arabia

International assessments provide a broader perspective for the assessment of the outcomes of education systems, not only in terms of student performance but also in terms of looking at the situation from an aggregate perspective. The differences in outcomes may result from the individual characteristics of students and also from the features of the school. It should be borne in mind that students with different backgrounds are rarely randomly assigned to schools, leading to socioeconomic or ethnic disparities, magnifying differences between schools. Various problems and needs require separate solutions, so policies should take this into consideration. However, in the first step, we should verify whether we are actually dealing with diverse schools, and then identify problems and needs and their scale.

Saudi Arabia participated first in the TIMSS in 2003 with a focus on 8th-grade students, and since 2011 its participation as included both the 4th- and 8th grades. Recently, Saudi Arabia participated in the TIMSS 2019 assessment, which allows for an up-to-date evaluation of the situation of schools in this country as it was in the months before the pandemic. For the purpose of this study, only the results for 8th grade students and their schools will be taken into consideration.

Methodology and study tools

The data analyses have been run using data gathered from the 2019 TIMSS assessment for 8th-grade Saudi Arabian students (Mullis, Martin, Foy, Kelly & Fishbein, 2020). In addition to assessing student competencies in mathematics and science, the TIMSS framework includes questionnaires administered to the students themselves, their teachers and the school principals. When analyzed together, the answers to these questionnaires give a comprehensive and internationally-standardized picture of the status of the educational system in a given country.

To identify groups of schools we used k-means clustering and latent profile analysis. Clustering is the process of grouping similar observations. Clustering algorithms *"are presented with a set of data instances that must be grouped according to some notion of similarity"* (Wagstaff, Cardie, Rogers & Schroedl, 2001, p. 577). The aim is to minimize within-group differences and maximize differences between groups. The k-means is one of the methods used for the allocation of an entity to the appropriate group. In order to perform it, the following steps are followed:

1) Choice of the number of groups - k.
2) Selection of initial seeds ("means") – centroids for k clusters.
3) Assigning each observation from the dataset to the closest cluster centroid (the distance of observations from centres is counted as Euclidean distance).
4) Recomputing centroids for each of the k clusters based on the assigned observations.

The procedure is repeated until the observations cease to change the group in subsequent assignments.

To determine the optimal number of clusters the Pseudo F index, which describes the ratio of between-cluster variance within-cluster variance, can be used. The selection of the number of clusters is based on maximizing the index:

$$Pseudo\ F = \frac{GSS/_{K-1}}{WSS/_{N-K}}$$

where GSS is the between-group sum of squares, WSS is the within-group sum of squares, N is the number of observations, and K is the number of clusters. In order to evaluate the clusters, we used three measures, namely the average school performance in mathematics, the average school performance in science, and the average sense of school belonging (which may reflect the well-being of students at school).

The latent profiles method was used as the robustness check for clustering. Kaufman and Rousseeuw (1990) define it as the classification of similar objects into groups, where the number of groups and their forms are unknown.

The latent profiles method helps with identifying the unobserved groups. It informs us of who is likely to be in a group and how that group's characteristics differ from others. In a typical latent class model, a latent class model is fitted with a categorical latent variable and categorical observed variables. A latent class model that instead of categorical has continuous observed variables is often referred to as a latent profile model. To build the latent profiles, we selected the following variables taken from the TIMSS questionnaires administered to students: average scores in mathematics and science, disorder during mathematics classes, clarity of mathematics, clarity of science, liking mathematics, liking science, confidence in mathematics, confidence in science, student sense of school belonging, bullying, and availability of home educational resources.

After selecting the number of groups, the optimal density (mean, variance) distributions (Gaussian) are determined for each variable. In this way the probability of belonging to a certain group in the case of a specified value of a variable is known. The probability of belonging to a class is calculated on the basis of the probabilities of all the given variables.

School clustering

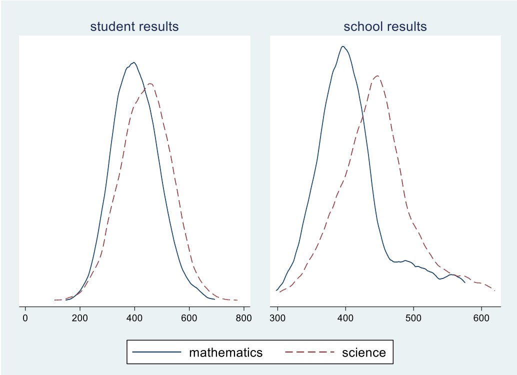
The TIMSS 2019 dataset for 8^{th}-grade students provides observations for 209 schools (Mullis, Martin, Foy, Kelly & Fishbein, 2020). The average school results were 409 for mathematics and nearly 446 for science, which corresponds to the intermediate international benchmarks[1]. The analysis showed that there is indeed a large gap between the highest and lowest performing schools, averaging 278 points for mathematics and 316 for science. The lowest school average result in mathematics was nearly 298 points, while the highest was 576 points. For science, these scores were 303 and 619 points, respectively.

When comparing mathematics and science performance at the student level and school level we can note that the science distributions are shifted to the right and inclined towards higher results, and that they also show higher variation, yet we deal with many low-performing schools.

This highlights the school segregation in terms of results; there are advantaged and disadvantaged schools, which create various educational opportunities. This has important consequences: policies targeting low- and high-achieving schools are different.

Figure 1.

Mathematics and science performance for student and school averages



Therefore, it seems appropriate to distinguish distinct clusters or profiles of schools based on patterns of observed characteristics and consider a more precise picture. For this purpose, the cluster analysis (k-means) and latent profile analysis (LPA) were carried out. In the first approach the schools are split into a set of predefined groups, so that those in the same group are as similar as possible and in those different groups are dissimilar in terms of specific features. The second method assumes that there are some latent constructs that are not directly measurable; however, examining common contextual features of schools reveals the hidden patterns and identifies the school profiles. The results would be useful for linking school profiles, identifying the problems faced by different schools, and the implementation of strategies for a school's policy on equal opportunities.

A preliminary analysis of school performance has shown that there are high performing and

[1] https://timss2019.org/reports/achievement/

low performing schools. We thus run a separate analysis. Based on the average scores of schools, clustering was performed using the k-means method. To determine the number of clusters the elbow and silhouette methods were used. The results of the use of the first method indicated 2 or 3 clusters to be the optimal solution, while the silhouette suggested 2 clusters. In the cases of two clusters their size was highly disproportionate, therefore it was decided to split schools into 3 groups representing respectively low-, average- and high performing students. Table 1 shows the outcome of the clustering of schools, showing how many of them can be found in each cluster. The estimations show that there is a large proportion of schools (56%) with average results, equalling 408 points for mathematics and 452 for science; moreover, highly underperforming schools exhibit mean results equal to 356 for mathematics and 381 for science. The mean results of schools that were classified as high performing were 512 and 543 points for mathematics and science, respectively

Table 1.

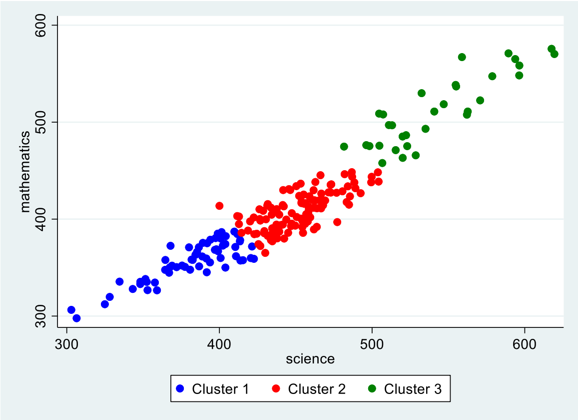
Characteristics of clusters of schools

Schools	Number of schools	Mean math result	Mean science result
Low performing	60	356	381
Average performing	117	408	452
High performing	32	512	543

The following scatterplot presenting relation between results indicates an existing correlation between them, i.e., if school average performance in science is high, it also achieves high results in mathematics. In particular, Figure 2 shows how there is almost a linear correlation between the achievements in mathematics and the ones in science, with the different colors indicating the cluster to which each school belongs. Figure 3 shows the distribution of the average science and mathematics results in defined clusters.

Figure 2.

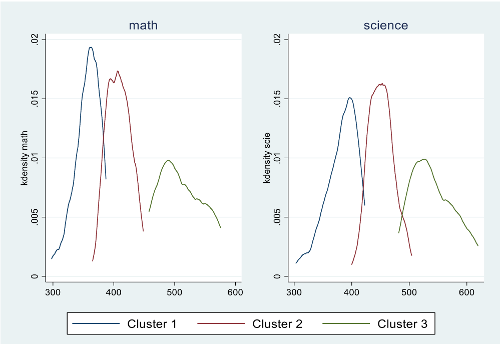
Scatterplot of average school math results on science results



Source: Authors' own calculation using TIMSS 2019.

Figure 3.

Distribution of average school mathematics and science results by clusters



Source: Authors' own calculation using TIMSS 2019.

There can be many factors behind such a distribution of results. School context is made up of various kinds of resources, therefore the disparities may result from many dimensions. We should look at social, cultural, economic factors, including school infrastructure, the area, social capital of students, parents, teachers, and principals.

School characteristics by school cluster

Although the clusters were identified using student performance only, they may differ also due to other factors that may explain the variation in performance. The characteristics of the three groups of schools are presented below and may help us to arrive at a better understanding of their characteristics and problems.

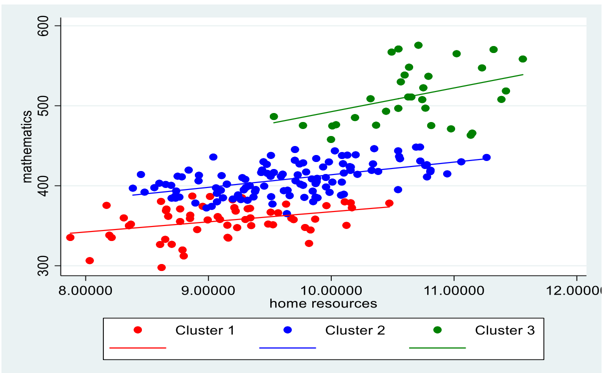
Socioeconomic factors

The most common variable distinguishing schools is the socioeconomic index, often recognised as the predictor of students' achievement. According to Garcia & Weiss (2017) schools are socially segregated; if only students were randomly assigned to schools the problem of socioeconomic disparities would not exist. Other studies by Caldas & Bankston (1997) and Perry & McConney (2010) indicate that students from disadvantaged backgrounds make more progress if they attend schools with a higher proportion of students with a high socioeconomic status. This may also be the case with Saudi Arabian schools, where for 69% of schools assigned to the third group more than 50% of students are economically affluent; the same is true for the 26% of schools from the second group and every third school from the first group.

The analysis of the relation between the students' home educational resources and educational results confirms that economic situation and access to educational materials affect student performance, which is especially visible for students from schools in the third cluster, where the those with the least disadvantaged background belong.

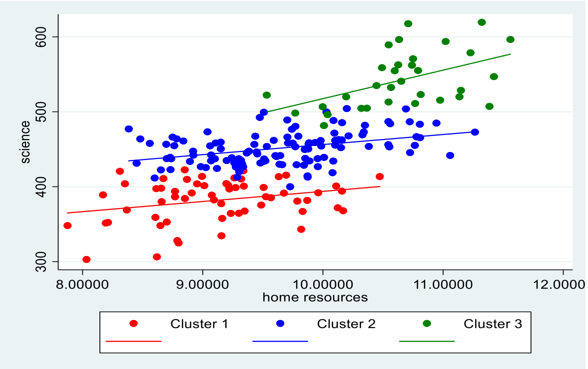
Figure 4a.

Relation between mean student home educational resources and math results



Source: Authors' own calculation using TIMSS 2019.

Figure 5b. Relation between mean student home educational resources and science results



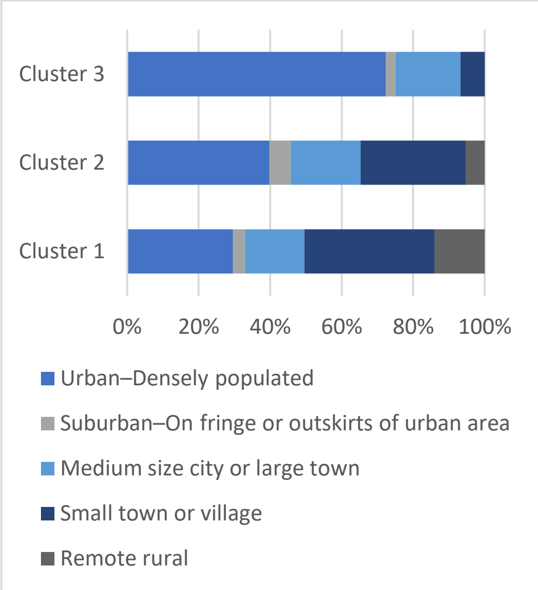
Source: Authors' own calculation using TIMSS 2019.

School location

According to global trends, schools with lower results are often located in smaller towns. This is often associated with a worse economic situation of schools, which may result from the their financing mechanism, but also from the economic situation of the inhabitants. It may also be related to the outflow of better educated people to cities in search of a better job or future for themselves and their children. TIMSS data suggests that a similar pattern exists in Saudi Arabia, where over 72% of high performing schools are located in densely populated urban areas. Only 6.81% are placed in small towns or villages, 18.15% in medium size cities or larger towns and 2.64% in the suburbs or outskirts of urban areas. None of the highly performing schools is placed in remote rural areas.

Figure 6.

School location by cluster



Source: Authors' own calculation using TIMSS 2019.

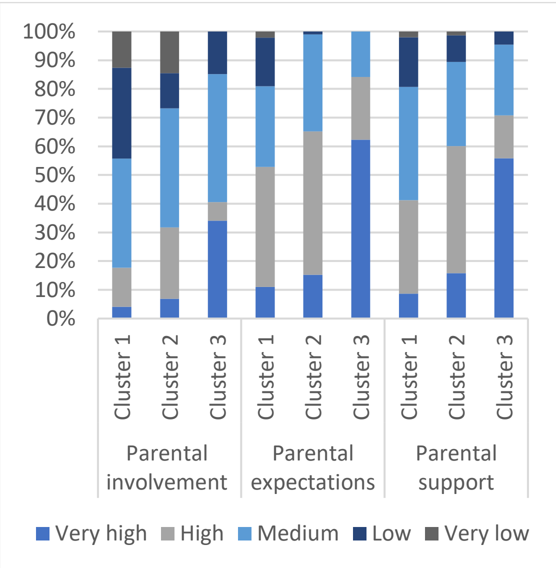
Due to the fact that the school infrastructure often depends on its location, it should be mentioned that, contrary to intuition, the highest performing schools more frequently reported an instruction significantly affected by resources shortages. This may not necessarily reflect the actual quality of these schools' infrastructure, but rather the higher expectations of the principals of better schools.

Parental involvement in students' education

When talking about expectations, we should also refer to those set by parents. Parents may show varying levels of support for and interest in their children's education, which may be related to their own educational experiences. Lara & Saracostti (2019) revealed that students' academic achievement differs in terms of parental involvement profiles. Children whose parents have a higher degree of involvement have higher academic results. Looking at the data, it is clear that the third group receives more support from parents, who are more willing to get involved in school life and also express higher expectations. This pattern may confirm that most education-oriented parents send their children to higher-performing schools. However, parental involvement is a factor that is difficult to directly influence through educational policy.

Table 2.

Share of schools in terms of parents' attitudes, as identified by principals.



Source: Authors' own calculation using TIMSS 2019.

Teachers' characteristics

According to the principal's opinions teachers employed in high performing schools usually have usually higher expectations. In the 94% of schools in the third cluster the principals declared that their teaching staff have high or very high expectations, compared to the 74% and 63% of schools in the second and first cluster, respectively. This is in line with the assumption that teachers account for the quality of the school when applying for jobs or that the higher performing schools attach greater importance to the quality of the teaching staff. When looking at the teachers' credentials, they mostly have a bachelor's degree or equivalent, regardless of the cluster; however, teachers employed in high performing schools are more likely to report having a masters' or doctoral degree.

Table 3.

Distribution of teachers by education, professional development, and clusters

	Science			Mathematics		
	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3
	Education					
Upper secondary education	0.0	0.2	4.1	0.0	0.0	0.0
Post-secondary, non-tertiary	0.0	1.3	2.3	0.0	0.0	0.0
Bachelor's or equivalent level	95.0	93.1	78.1	98.7	99.8	89.9
Master's or equivalent level	5.0	5.4	12.6	2.3	0.2	11.1

Doctor or equivalent level	0.0	0.0	2.9	0.0	0.0	0.0
	Professional development					
None	11.8	4.5	5.4	8.9	7.8	4.5
Less than 6 hours	15.0	7.8	24.8	19.8	10.2	6.3
6-15 hours	34.4	29.2	19.0	39.1	25.3	38.3
16-35 hours	21.3	28.7	18.8	18.2	30.5	17.3
More than 35 hours	17.5	29.8	32.0	14.0	26.2	33.7

Source: Authors' own calculation using TIMSS 2019.

When comparing the values of indices based on teachers' responses concerning school conditions for school clusters, we can note that those in schools assigned to the third cluster report a larger emphasis on academic success; they are also less likely to admit that teaching is limited by students' needs. Teachers employed in schools belonging to the first cluster have the worst working conditions. When considering job satisfaction, the teachers from cluster 2 show the highest level.

Table 4.

Comparison of mean values in school clusters for indices based on teachers' responses

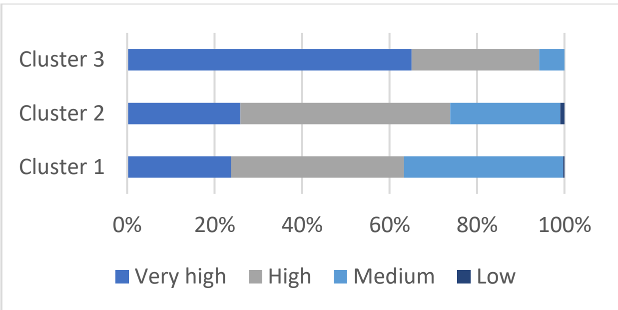
	Cluster 1		**Cluster 2**		**Cluster 3**	
	mean	S.E.	mean	S.E.	Mean	S.E.
School Emphasis on Academic Success	10.32	0.00	11.31	0.00	11.92	0.00
Teaching Limited by Student Needs	8.94	0.00	9.81	0.00	10.73	0.00
Safe and Orderly Schools	10.76	0.22	11.67	0.15	11.68	0.47
Teachers' Job Satisfaction	10.82	0.00	11.10	0.00	10.84	0.00

Source: Authors' own calculation using TIMSS 2019.

As in the case of students, we should also deal with the problem of absenteeism among teachers, which affects educational quality and has important consequences for students (Rogers & Vegas, 2009). The higher the incidence of this problem the more significant is the decrease student achievement (Miller, Murnane & Willett, 2008). One third of principals from the first school group admitted that the absence of teachers is a moderate or serious problem in their schools, compared to 23% in the second and 10% in the third clusters. Moreover, we also found that in the first and second clusters the expectations of teachers related to the school are less frequently "high" or "very high" than in the third cluster (Figure 6), which indicataes how teachers tend to have lower expectations when working in schools in which students exhibit lower educational achievements.

Figure 7.

Schools in terms of teachers' expectations, as identified by principals



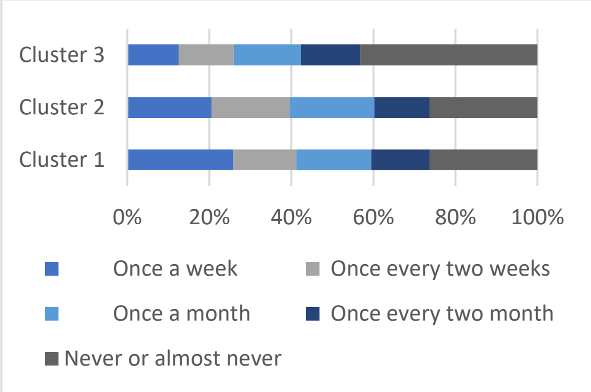
Source: Authors' own calculation using TIMSS 2019.

Students' characteristics

In schools with the highest results principals more frequently identified a student desire to do well. According to over 40% of principals from the first group, their schools placed a very high emphasis on academic success, compared to 23% of schools in the second and 9% in the first clusters. Also, in the highest performing schools moderate-to-severe discipline problems were identified less frequently; they concerned 10% of these schools, 17% of the average and 28% of the highly underperforming schools, where student absenteeism is more frequently a moderate or a serious problem. According to Robinson et al. (2018) regular school attendance plays a critical role in students' success, especially in the early stages of education. The negative effects appear regardless of the economic situation, ethnicity or gender of students (Gottfried, 2010). Figure 6 compares the students' responses on how often they skip school. Students attending higher performing schools are less likely to skip classes - 43% of students in the third cluster never or almost never skipped school, compared to 26% of those in the second and first clusters, where one in five and one in four students is absent from school once a week, respectively. The aim of policy in this area should be to identify the reasons for absence; both students' unwillingness to attend and transportation issues (Balfanz & Byrnes, 2013) may be responsible, and action should be taken to encourage students to attend classes.

Figure 8.

Proportions of students in school clusters in terms of being absent from school.



Source: Authors' own calculation using TIMSS 2019.

Holmes & Croll (1989) found a positive relation between the amount of time students spent on homework and their academic performance, even after controlling for family background. Table 5 compares the distribution across six categories, reflecting the time spent by Saudi Arabian students on doing homework. Regardless of the school cluster, the majority of students spend up to 15 minutes on homework. More students from high performing schools (40%) spend over 15 minutes on mathematics, compared to students from other schools (26% and 24%); however, when considering science, students from the first cluster more frequently report spending more than 15 minutes on homework. It should be noted that the time spent on learning may also depend on the students' skills. If students feel comfortable in a subject, the homework may take less time.

Table 5.

Time spent on homework

	Mathematics			Science		
	Cluster 1	Cluster 2	Cluster 3	Cluster 1	Cluster 2	Cluster 3
My teacher never gives	3.9	1.2	0.9	7.4	4.9	1.6
1–15 minutes	70.2	74.7	58.9	60.9	72.3	71.3
16–30 minutes	21.3	19.8	29.9	20.9	15.6	20.2
31–60 minutes	4.3	4.2	8.7	6.1	4.0	5.0
61–90 minutes	0.1	0.1	1.3	2.2	1.6	1.4
More than 90 minutes	0.2	0.1	0.3	2.5	1.5	0.5

Source: Authors' own calculation using TIMSS 2019.

Table 6 compares the mean values of indices for students attending schools assigned to different clusters. Students from cluster 3 are in the most favorable situation when it comes to home educational resources, where differences between students are significant. Significant differences also occur due to student bullying. This problem affects mainly students from schools in the first cluster, where 14% of students declared they experienced bullying about weekly and 24% about monthly. In cluster 2 these values are 5% and 18%, and 4% and 19% in cluster 3. Similarly, the largest problem with disorderly behavior during math lessons concerns students from the first cluster. When it comes to students' attitudes towards subjects, significant differences arise in the case of students' confidence in science - students from high performing schools (cluster 3) are the most confident, and those from disadvantaged schools the least. A similar pattern can be observed with confidence in mathematics; here also students from the highest performing schools feel the most confident, though the difference is significant only between first and second clusters. In other cases, the differences between students in the school clusters are not significant, even when in the students' sense of belonging.

Table 6.

The average values of student indices for school clusters

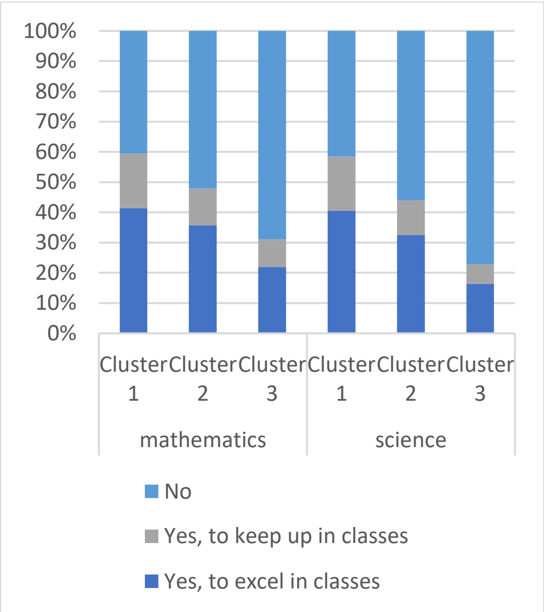
	Cluster 1		Cluster 2		Cluster 3	
	mean	S.E.	mean	S.E.	mean	S.E.
Home Educational Resources	9.07	0.06	9.58	0.06	10.60	0.15
Students Sense of School Belonging	10.22	0.10	10.23	0.07	10.01	0.14
Less Student Bullying	9.76	0.11	10.45	0.06	10.40	0.14
Students Like Learning Mathematics	10.22	0.08	10.07	0.08	9.81	0.15
Instructional Clarity in Mathematics	10.47	0.07	10.60	0.07	10.47	0.17
Disorderly Behavior during Math Does not mentioned in science?	9.80	0.08	10.15	0.07	10.35	0.32
Student Confident in Mathematics	10.31	0.07	10.65	0.06	10.45	0.14
Students Value Mathematics	10.24	0.09	10.06	0.07	9.95	0.12
Students Like Learning Science	10.38	0.09	10.65	0.08	10.85	0.22
Instructional Clarity in Science	10.59	0.08	10.77	0.08	10.97	0.21
Student Confident in Science	10.33	0.08	10.86	0.06	11.15	0.18
Students Value Science	10.79	0.08	10.71	0.08	10.86	0.16

Source: Authors' own calculation using TIMSS 2019.

Students from low- and average performing schools are more likely to attend extra classes both in mathematics and science in order to excel. In the case of mathematics, this was declared by the 60% of students form the first cluster compared to 31% in the third cluster, while in science it was 60% and 23%, respectively.

Table 7.

Proportion of students attending extra lessons in mathematics and science by school cluster



Source: Authors' own calculation using TIMSS 2019.

School performance

After identifying the main differences between school clusters, regressions of the mean mathematics and science results were conducted. For the analysis the school, teacher and student level variables were selected. Student and teacher variables were transformed into school means. All the variables were expected to have positive signs as they had higher values for students reporting positive attitudes.

As Table 6 indicates, before clustering all the variables had a significant impact on the mean math results, but after grouping schools by achievement only some of them remained significant. The home educational resources significantly influence schools from the first and second clusters. In line with intuition and research, improving access to educational materials can improve their educational outcomes. From the point of view of cluster 1, reducing bullying should also improve student performance. Regardless of the cluster, clear action should be also taken to reduce student absences, as this factor is strongly positively related to students' performance; however, the advantaged schools (cluster three) would benefit the most.

To conclude, the analysis of the mathematics results indicated that undesirable behaviors among students should be targeted. It is also important to provide access to educational materials to those for whom they are limited, e.g. due to the family's financial situation.

Table 8.

Regression explaining mean mathematics results in school clusters

Variable	Without clustering		Cluster 1		Cluster 2		Cluster 3	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Home educational resources	26.81*	3.49	14.10*	4.56	10.50*	2.68	24.74	15.02
Experiencing less bullying	13.16*	2.44	6.81*	3.18	-3.75	2.30	3.96	9.03
Being less absent at school	11.45*	3.57	0.33	4.52	5.93*	2.77	41.39*	8.32
Spending more time on math homework	42.35*	9.15	-19.46	11.44	-0.29	9.61	23.33	13.79
Math teacher opinion on safe and order	2.44*	1.15	1.78	1.39	-0.02	0.86	-3.00	3.72
Total number of computers at school	0.97*	0.23	0.13	0.34	0.21	0.19	-0.28	0.29

*Note:** $p<0.05$

A similar analysis was carried out for the mean results from science. Table 9 demonstrates a clear, significant association between home educational resources and science results; in this case the positive impact of home resources is also true for the advantaged schools. When considering bullying, limiting the incidence of violence at school is important for students from cluster 2. Similarly to math, here also the students from cluster 3 can benefit most from the reduction of absenteeism. The attitude towards science is also important, and its positive and significant influence is noticeable in all school clusters. The analysis also showed that in the case of science results, the availability of computers in the school (expressed by the number of computers) is also important for the second cluster.

In conclusion, the analysis of the mean results from science showed small discrepancies compared to the case of mathematics, but the general conclusions are similar - particular attention should be paid to the problem of bullying, student absenteeism and home educational resources, and school facilities that can compensate for lack of educational materials at home. Moreover, the students' attitude to the subject is crucial.

Table 9.

Regression explaining mean science results in school clusters

	Without clustering		Cluster 1		Cluster 2		Cluster 3	
	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.	Coef.	S.E.
Home educational resources	23.91*	4.12	15.51*	6.22	10.75*	3.12	36.81*	16.07
Experiencing less bullying	19.68*	3.22	13.67*	4.14	2.65	3.28	5.99	10.71
School belonging	-10.14*	3.41	-3.52	4.57	-7.02*	3.11	-1.66	5.61
Like science	20.43*	3.29	14.06*	6.53	9.75*	2.19	21.41*	7.47
Being less absent at school	-2.02	4.61	-16.21*	6.98	-8.96*	3.71	27.00*	9.33
More hours spent by teacher on professional development	3.18	2.01	-0.61	2.58	-0.57	1.60	-0.87	4.59
Teaching limited by student needs in teachers opinion	4.55*	1.38	1.34	2.04	1.00	1.05	4.69	4.72
Total number of computers at school	1.06*	0.25	0.40	0.42	0.27	0.21	-0.12	0.25

*Note:** $p<0.05$

Latent profile analysis of schools

The alternative way of grouping schools applied in this report is Latent Profile Analysis (LPA), which specifies the number of school profiles in the data. For each school the probability of being assigned to a specific profile is estimated and the classification into a profile depends on the highest profile probability (Wen et al., 2020). Schools belonging to the same profile are similar to each other because their response patterns are generated by the same probability distribution (Lambe & Bristow, 2011). As school quality has many dimensions, we identify the latent classes using students' characteristics, teachers' attitudes, school facilities and human relations. To evaluate the latent profile models the Bayesian information criterion (BIC) was used, with the lowest value indicating the best latent profile solution. This indicated 4 profiles to be optimal for Saudi Arabia schools.

Comparing the k-means school allocation with LPA, we see that 80% of schools from the first cluster (with the lowest educational results) were assigned to the first class. Nearly 56% of the schools from second cluster were assigned to the second class, the remaining schools split almost equally between the first and fourth class. Most schools from cluster 3 were assigned to class 3. Generally, clusters 1 and 3 overlap with classes 1 and 3. It is worth mentioning that class 3 differs slightly from class 2 in terms of mathematics and science results, the differences mainly being due to other variables. In this class students achieve higher results than those from the first and second classes despite having the largest problems with absence, homework and low school belonging and low confidence in subjects; however, the teachers' experiences and school facilities are rather positively evaluated.

The inclusion of additional variables gave us slightly different results in latent classes than in clustering; however, groups with the highest performing and the lowest performing schools in terms of mathematics and science results overlapped.

Table 10.

Proportions of schools clustering in groups created by the latent profile model.

		Cluster		
		1	**2**	**3**
Class	**1**	80.00	21.37	0.00
	2	13.33	55.56	6.25
	3	0	1.71	84.38
	4	6.67	21.37	9.38

Source: Authors' own calculation using TIMSS 2019.

Table 11.

Basic characteristics of school profiles

	number of schools	**mean math result**	**mean science result**
Class 1	73	371	398
Class 2	75	405	452
Class 3	29	513	543
Class 4	32	411	450

Source: Authors' own calculation using TIMSS 2019.

In the next step, analogous regressions to those carried out in the process of clustering were performed, with some discrepancies due to different grouping methods. In the first class, the index representing bullying is significant. Thus, reducing bullying can improve the math outcomes of these schools. Except for the third class, the significant impact of home educational resources was revealed. However, it should be mentioned that for the third class educational resources and bullying were near the significance level. Unequivocally, school absence significantly affects students from this group. When it comes to time spent on math homework it may significantly improve the educational performance of students from the second class.

Table 12.

Regression explaining mean mathematics results in school profiles

	Class 1		Class 2		Class 3		Class 4	
	Coef	S.E.	Coef	S.E.	Coef	S.E.	Coef	S.E.
Home educational resources	20.21*	6.05	10.26*	4.73	44.72	21.88	27.42*	10.20
Experiencing less bullying	11.55*	4.15	4.32	3.63	22.42	10.88	7.29	10.55
Being less absent at school	6.75	5.87	5.59	4.56	56.63*	10.65	22.92	13.28
Spending more time on math homework	-15.38	15.62	42.63*	16.21	32.27	16.41	1.15	37.11
Math teacher opinion on safe and order	2.19	1.77	0.75	1.47	-0.55-	3.94	-1.99	2.75
Total number of computers at school	0.67	0.43	0.34	0.36	-0.04	0.33	0.15	0.50
_cons	45.99	86.48	125.71	81.95	-510.75	208.65	15.74	184.97

Note: * p<0.05

For science, it should be noted that among the lowest performing schools bullying and home educational resources affect students results the most. In the second class, bullying, school belonging and attitude towards science were significant. Slightly surprising is the negative impact of the school belonging index. In the third class, home educational resources, liking science and being less absent at school are most important. Latent classes revealed patterns that were not noticeable in the clusters. In the fourth class, home educational resources and attitude towards science turned out to be significant.

Table 13.

Regression explaining mean science results in school profiles

	Class 1		Class 2		Class 3		Class 4	
Column 1	Coef	S.E.	Coef2	S.E.3	Coef4	S.E.5	Coef6	S.E.7
Home educational resources	17.64*	8.80	9.20	5.03	58.14*	17.16	40.54*	11.53
Experiencing less bullying	17.30*	5.51	9.14*	4.38	14.17	9.02	0.02	11.79
School belonging	-3.66	6.89	-12.53*	3.88	1.92	5.47	-10.12	7.73
Like science	6.99	11.16	13.63*	4.68	24.55*	7.82	21.75*	9.28
Being less absent at school	-11.32	8.69	-7.55	5.40	39.06*	9.06	-6.68	17.24
More hours spent by teacher on professional development	1.11	3.39	4.38	2.51	6.70	5.06	8.55	5.06
Teaching limited by student needs in teachers' opinion	4.67*	2.33	5.17	1.53	6.61	3.63	-2.94	3.64
Total number of computers at school	1.10*	0.54	0.25	0.34	0.00	0.22	0.54	0.54
_cons	-7.67	172.42	192.80	95.32	-774.80	165.46	-54.54	164.47

Note: * p<0.05

Conclusions and recommendations

The cluster analysis revealed the characteristics of the low- average- and high-performing schools in Saudi Arabia. The **lowest achieving schools** generally aggregate students in worse economic situations. This may be partly related to their location; in Saudi Arabia disadvantaged schools are often placed in less populated areas, which is consistent with worldwide trends. The problem of students assigned to the school cluster with the lowest results is also the lack of expectations and support from parents. When considering teachers, that they are more likely to devote less time to professional development than their colleagues from higher performing schools. Also, the problem of their absenteeism is clear. In teachers' opinion their schools put less emphasis on academic success and are generally not so safe and orderly. Interestingly, there is no significant difference in the teachers' level of job satisfaction, compared to teaching staff from highest performing schools. When it comes to students, they are not motivated. In addition, the problem of absenteeism and bullying and other disorderly behavior affects them. Students' attitudes to certain subjects should also be improved. The picture of disadvantaged schools produced by the analysis is consistent with the literature. The **middle achieving schools** also deal with the problem of inadequate home educational resources and absenteeism of both teachers and students. The attitude of students to some subjects is also problematic. Considering the **highest performing schools**, they provide the best educational conditions; however, they also frequently suffer from students' absenteeism. Students do not like and value math, like their colleagues from worse performing schools.

To summarize, there is some grouping of social and economic capital in Saudi Arabian schools. There is a clear division between schools and a pattern showing that the higher results are a result of better conditions, relations, and atmosphere.

The latent profile analysis confirmed that there is some division in terms of mean school performance and student, teacher, and school characteristics. The results are generally consistent with the cluster analysis; however, a group of schools that achieve higher results than second class was revealed, despite greatest problems of disorder and poor students' attitudes.

The quality of schools can be considered in many dimensions. While often research is limited to the analysis of the educational results, quality is a much broader concept, and the characteristics of students, parents, teachers, and school environment should also be accounted. This way, is it possible to obtain a real picture of a school, define its needs, and develop the appropriate policy. If, as in the case of Saudi Arabia, there are differences between schools, applying one policy will be ineffective. Moreover, the problems of disadvantaged schools must be dealt with, but the development of other schools should not be prevented. Thus, we identified schools with problems of different scale, and the following recommendations are targeted accordingly.

Recommendations for the disadvantaged group of schools (with the lowest academic results)

In these schools, material support for students is indispensable, including providing access to appropriate educational materials that they cannot access at home. Policies specific for these schools should also focus on linking parents with schools. In disadvantaged families, parents are usually less likely to be involved in their students' education, which also translates into the students' approach to education - students from the most disadvantaged schools present lower levels of motivation, so the creation of motivational programs for them should be considered. Also, absenteeism and the problem of bullying should be monitored closely. The disorder problem common in these schools also requires providing targeted teacher education to furnish them with the knowledge and skills needed for working with disadvantaged students. Teachers should not lower their expectations because of students' problems with education but adapt their practices and strategies to the students' needs. The development of working conditions and financial incentives that can attract high quality teachers could also be considered. One possible intervention is that effective teachers should be compensated and professionally developed to encourage them to not move to other schools or roles. It is also worth controlling the absence of teachers and verifying its causes.

Recommendations for the middle-achieving schools

In the case of these schools where students achieve average results, the educational policy should also focus on providing them with educational materials. The creation of a teacher control program that would limit absenteeism is also required. It is likewise necessary to identify why students miss classes: is this a matter of lack of motivation, or are there any other reasons related to transportation or their teachers' absenteeism? These schools, like those in the most disadvantage school group, are most likely to be located in small cities or communities, which requires considering motivation policies for retaining their most effective teachers and encouraging others to join. The aim of these schools should also be to improve students' attitude towards the subjects.

Recommendations for the highest-achieving schools

As with the two previous groups of schools, attention should be paid to the problem of absenteeism. Although students in these schools do best in the subjects they study, their attitudes towards the subjects need improvement. Another recommendation here is to share with the other groups the practices that are more likely to improve their students' performance, and maintain a dialogue with other schools to help them catch up.

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