Modeling the Predictive Factors of Moroccan Secondary School Students' Motivation to Learn Geology: A Mixed-methods Study

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***Abstract*—Despite the richness and economic importance of geology in Morocco, secondary school students show limited motivation to learn the subject. This study aims to analyze the factors influencing the motivation of Moroccan secondary school students to learn geology. A Geology Motivation Questionnaire II was used to examine the influence of gender, place of residence, class and geology marks on student motivation. Multiple linear regression analyses were performed on 2053 high school students. The results showed that gender has a significant impact on student motivation, with girls more motivated than boys to learn geology. Geology marks also had a significant, but negative effect on motivation (the lower the marks, the lower the motivation), particularly on students' self-efficacy and self-determination. Home environment shows relatively weak effects, while class differences have no significant and consistent effects. However, a general trend shows that motivation decreases with advancement in schooling. The regression model explained 21.6% of the total variance in the predictors of Moroccan geology students' motivation. In addition, interviews with 26 students confirmed and enriched these results by identifying other factors influencing motivation, such as socio-familial environment, previous experiences, quality of teaching practices and digital literacy.**

***Keywords*—geology, learning, Moroccan students, motivation, secondary school**

I. Introduction

The study of student motivation has been one of the most exciting areas of research in science education since the 1980s. Motivation is a key element in any learning process [1], particularly in scientific learning, where it requires a combination of cognitive abilities, specific skills and sustained effort to acquire a thorough understanding of scientific concepts. For Salih *et al.* [2], motivation is a complex psychological concept that aims to explain behavior and determine the level of effort expended when performing various activities. What's more, it has a considerable influence on learning and performance [3]; more successful students are often highly motivated to learn, and the same is true vice versa [4]. In the same vein, Satrianti *et al.* [5] point out that students' performance in science is influenced by their motivation during learning. Indeed, motivational factors are among the most powerful predictors of students' future perseverance in science [6, 7]. Furthermore, motivation is one of the main predictors of academic success, regardless of a student's intelligence level [8]. Improving student motivation also remains one of the main concerns of teachers in the educational context [9]. This situation calls for the creation of a favorable learning climate, capable of stimulating and maintaining student motivation when learning science. To achieve this, it is essential to implement varied pedagogical strategies, aimed at making science more attractive by anchoring it in students' everyday lives and linking it to their future academic and professional aspirations. This includes improving teachers' skills and classroom practices, fostering science learning outside the classroom by providing supportive environments [10], but also promoting a sense of belonging to the classroom and school [11].

However, motivation is a complex, multidimensional concept [10, 12, 13], and scientific learning is an equally complex process, influenced by the interaction of multiple variables, both subjective (linked to the student) and objective (beyond the student's control). It is therefore difficult for teachers to anticipate and control these factors during the learning process. Motivational factors thus present a contextual enigma that teachers need to decipher. In this context, scientific research has shown that, even under identical teaching conditions, students' motivation to learn science varies according to several factors, including differences in grade level [14, 15], place of residence [16] and gender [17]. These observations highlight the existence of other factors affecting student motivation in science, which deserve to be explored to make learning these disciplines more attractive. This is the perspective of our research.

Motivation to learn science, as conceived in Albert Bandura's social cognitive theory [18–20], can be defined by extension as "the internal state that elicits, directs and sustains science learning behavior" [21]. It is a multifactorial construct that influences self-regulated learning and includes, in particular, intrinsic motivation, self-determination, self-efficacy and extrinsic motivation [21]. The latter refers to learning science in order to achieve concrete goals, such as a career or a good mark [22]. These motivational dimensions have been widely measured in different countries and scientific disciplines using a psychometric tool (SMQ-II) developed by Glynn and collaborators in 2011 to assess motivation in science.

A. Problem Statement

Despite efforts at educational reform and recognition of Morocco's geological wealth, as well as its scientific and economic importance [23], the teaching of geology has not undergone any significant evolution and faces several obstacles [24]. Furthermore, our professional and training experiences, as well as those of our colleagues, reveal that students perceive geology as a boring and little attractive discipline. In fact, they display a notable lack of motivation and interest in learning it. This lack of motivation can be explained largely by the influence of certain demographic variables, including gender, place of residence, and school level, as well as students' performance in geology [23]. These variables therefore need to be examined using advanced statistical analyses, such as correlation and multiple regression tests, in order to better understand their influence on students' motivation to learn geology.

Moreover, several pedagogical factors may explain this lack of interest in geology among Moroccan students. These include the absence of empirical approaches, the ineffectiveness of teaching methods used in the classroom [25], and the complexity of geological concepts [26–29]. This situation is also linked to a lack of knowledge of the different fields of application of geology [26], particularly among Moroccan teachers with initial training in biology [29, 30]. What's more, the school guidance system in Morocco tends to marginalize geology-related streams in favor of biology-oriented ones [30], which could partly explain the remarkable reluctance towards geology studies in Moroccan universities. As an example, at the Faculty of Sciences in Fez, the number of students enrolled in geology did not exceed 17 per year between 2005 and 2011 [27].

Furthermore, an analysis of existing Moroccan literature highlights the scarcity of didactic work on the teaching and learning of geology, compared with other scientific disciplines such as biology or physics. No specific studies have been carried out in Morocco, or internationally, on student motivation in geology. Similarly, no didactic work has used the SMQ-II in Morocco to assess motivation in a specific scientific field, nor worldwide to study motivation in the field of geology.

Previous work also points out that motivation occupies an important and privileged place in pedagogy compared to science didactics [23]. Pedagogy sees motivation as a goal to be achieved at the end of learning, while science didactics focuses mainly on the construction and acquisition of scientific knowledge, neglecting the motivational aspect. This raises two fundamental questions: *how can an unmotivated student acquire basic scientific concepts and knowledge? And in the case of a student's lack of motivation and interest in a given subject, can the specific learning objectives be achieved?*

In summary, this research is based on three main issues that justify its relevance: the lack of interest and motivation of Moroccan students in learning geology, the absence of studies on student motivation for learning this subject worldwide, and finally, the scarcity and dispersion of Moroccan literature concerning the didactics of geology compared to other scientific disciplines.

B. Research Aim and Research Questions

Aware of the crucial importance of understanding and analyzing the complex dimensions of student motivation in the learning process, and in order to contribute to enriching the still scarce and scattered Moroccan literature in the field of geology didactics, we set out to study the factors influencing Moroccan students' motivation to learn this discipline in secondary school. The aim is to make geology more attractive and optimize its learning. To achieve this objective, two research questions were formulated:

(1) Do differences in gender, school level, place of residence and marks obtained in geology influence students' motivation to learn the subject?

(2) What other factors might influence students' motivation to learn geology?

II. Research Methodology

A. General Background

This study adopted a mixed research methodology combining quantitative and qualitative approaches to collect data from Moroccan students. The quantitative data collected via the GMQ-II made it possible to explain the five components of students' motivation to learn geology according to gender, school level, place of residence, and marks obtained in this subject, which required multiple linear regression analyses. To enrich and complement the quantitative results, as well as to broaden the scope of this research, a qualitative analysis was conducted based on transcripts of semi-structured interviews. This method proved to be more effective in interpreting the possibility that other factors influence students' motivation to learn geology.

This methodology allows us to deepen the research and strengthen our understanding of the factors influencing students' motivational components with regard to learning geology. It also aims to obtain precise and scientifically valid results, likely to advance geological learning, while providing complementary qualitative insights.

The student data collection process took place from March the 15th to June the 10th of 2024. It occurred in two distinct phases:

- Distribution of the GMQ-II questionnaire in paper format, to assess the five components of motivation to learn geology according to criteria such as academic progress, gender, place of residence or marks obtained in the subject.
- Semi-structured individual interviews to complement the quantitative results with more in-depth qualitative perspectives.

B. Legal and Ethical Aspects

In accordance with the ethical and legal requirements of scientific research, institutional approval was obtained from the Marrakech-Safi Regional Academy of Education and Training, as well as authorization from the Provincial Directorates of Education overseeing the schools concerned. The objectives of the study were explained to the students, and their participation was based on voluntary and informed consent.

The principles of confidentiality and anonymity were strictly upheld throughout the data collection and processing

phases.

C. Participants

The study involved a sample of 2053 students from 17 public schools in the Marrakech-Safi region of Morocco, who responded to the GMQ-II. Schools were selected on the basis of accessibility criteria, in accordance with the above-mentioned legal procedures.

Based on the power analysis performed using G*Power 3.1.9.7 software ($f^2 = 0.15$; $\alpha = 0.05$; power = 0.80; 4 predictors), the minimum sample size required to estimate a multiple linear regression model is 85 students. Thus, the total sample size used in this study ($N = 2053$) is more than sufficient to represent the target population.

Participants were characterized according to four main criteria: gender, place of residence, geology performance and school level.

- **Gender:** 53.7% of participants are girls and 46.3% are boys.
- **Place of residence:** 43.5% live in rural areas, 29.5% in semi-urban areas and 27% in urban areas.
- **Geology performance:** average geology marks were also taken into account: 21.6% of participants scored below 10, 55.3% between 10 and 15, while 23.1% scored above 15.
- **School level:** the participants covered six levels, with a proportion of students in the first (1YMS), second (2YMS) and third (3YMS) years of middle school (16.9%, 20.4% and 19.8%, respectively), as well as 19% of participants in the Common Scientific Core (CSC), 12.6% in the first (1BAC) and 11.3% in the second year (2BAC) of the baccalaureate in high school science streams.

D. Instrument and Procedures

This study is based on quantitative data collected using an adapted version of the Science Motivation Questionnaire II (SMQ-II) [21] contextualized for the Moroccan education system and to the objectives of the study. The adaptation followed a four-stage methodology, supervised by experts in pedagogy and science didactics, fluent in English and Arabic:

- Translation into Arabic language;
- Contextual adaptations: modifications to suit Moroccan context;
- Expert validation;
- Pre-testing with 80 students (middle and high school) to check clarity and consistency.

The final Geology Motivation Questionnaire-II (GMQ-II) adapted from QMS-II, comprises 25 items divided into five motivational dimensions: *intrinsic motivation, self-efficacy, self-determination, grade motivation and career motivation* (see Table 1).

Students are asked to respond to each item on a rating scale (Likert scale) ranging from *"Never (1)"* to *"Always (5)"*.

The GMQ-II was administered in paper format. The administration steps were as follows:

- **Demographic information:** Students indicated their gender, place of residence, school level and average geology mark.
- **Responses to motivational items:** Participants were asked to rate the 25 statements.
- **Duration:** Questionnaire administration took no longer than 15 min [21], ensuring effective participation without cognitive overload.

Table 1. Moroccan version of the Geology Motivation Questionnaire (GMQ-II)

Factors	Items
Intrinsic Motivation (IM)	The geology I learn is relevant to my life. Learning geology is interesting. Learning geology makes my life more meaningful. I am curious about discoveries in geology. I enjoy learning geology.
Self-Efficacy (SE)	I am confident I will do well on geology tests. I am confident I will do well in geology labs and integrated activities. I believe I can master geology knowledge and skills. I believe I can earn a grade of "**15**" in geology I am sure I can understand geology.
Self-Determination (SD)	I put enough effort into learning geology. I use strategies to learn geology well. I spend a lot of time learning geology. I prepare well for geology tests and labs. I study hard to learn geology.
Grade Motivation (GM)	I like to do better than other students on geology tests. Getting a good geology grade is important to me. It is important that I get an "15" in geology. I think about the grade I will get in geology. Scoring high on geology tests and labs matters to me.
Career Motivation (CM)	Learning geology will help me get a good job. Knowing geology will give me a career advantage. Understanding geology will benefit me in my career. My career will involve geology. I will use geology problem-solving skills in my career.

E. Validity and Reliability of GMQ-II

The SMQ-II has demonstrated content and criterion validity in previous studies [21]. In the present study, face and content validity were confirmed by the panel of experts in pedagogy and science didactics previously described. Construct validity was then examined through a Confirmatory Factor Analysis (CFA) conducted using AMOS software, version 23 (see Appendix A).

The CFA results show that all GMQ-II items are valid for measuring the motivational components of Moroccan students in geology and that the proposed model meets the recommended goodness-of-fit criteria, with a value of $\chi^2/df = 3.899$, RMSEA = 0.038, SRMR = 0.056, CFI = 0.957, GFI = 0.96, NFI = 0.943, AGFI = 0.951, and TLI = 0.951. Furthermore, the items exhibit standardized factor loadings ranging from moderate to high, with the lowest loading being 0.37, thus exceeding the factor loading criterion of 0.35 [31].

The reliability of the instrument was assessed using Cronbach's alpha, with values equal to or greater than 0.70 considered acceptable [32]. The obtained Cronbach's alpha coefficients (see Table 2) show that the Moroccan version of the GMQ-II has sufficient reliability for measuring Moroccan secondary school students' motivation to learn geology.

Table 2. Alpha values and number of items for each score

Components	Alpha values	N items
Intrinsic motivation	0.769	5 items
Self-efficacy	0.782	5 items
Self-determination	0.789	5 items
Grade motivation	0.728	5 items
Career motivation	0.851	5 items
Total score of items	0.911	25 items

These analyses show that the adapted instrument (GMQ-II) has both confirmed validity and robust statistical reliability, guaranteeing reliable results for our study.

F. Qualitative Data

In order to supplement the data collected with the GMQ-II, and to identify other factors likely to influence Moroccan students' motivation to learn geology, semi-directive individual interviews were conducted with 26 students (14 middle school students and 12 high school students). Of these, 14 were girls (54%) and 12 boys (46%), proportions similar to those observed in the overall sample of 2053 students who voluntarily completed the GMQ-II.

The interviews were conducted using a semi-structured guide developed from the GMQ-II and a synthesis of previous research on motivation in science. With regard to reliability and validity, Noble and Smith [33] point out that qualitative methods are still widely debated. In our study, validity was ensured by: rereading by a panel of experts and incorporating feedback from a pre-test conducted with 4 students.

The final version of the guide (Table 3), validated by the experts, includes 5 open-ended, simple and flexible questions, giving interviewees the space to express themselves freely about their ideas and conceptions without any restrictions. The interviews were carried out in the classrooms of 3 middle schools and 2 high schools with students who had completed, signed and returned the consent form on the day of the interview. Each interview lasted no more than 20 minutes.

Table 3. Questions and their objectives from the interview guide concerning motivation in geology

Questions	Objectives
Could you describe your motivation to learn the geology courses?	This question will enable us to assess students' motivation levels and underlying factors.
Could you explain what motivates you to learn geology?	This question explores the internal and/or external factors that motivate students to learn geology.
What discourages you from learning geology?	This question will explore the factors that may discourage students from learning geology.
In your opinion, what is not sufficiently taken into account in the geology program?	Both questions aim to reveal the factors that would enable students to take greater control of their learning and develop their autonomy.
What could be done to encourage more students to learn this subject?	

G. Data Analysis

To analyze the correlations between the dependent variables (intrinsic motivation, self-efficacy, self-determination, grade motivation and career motivation) and the independent variables (gender, school level, place of residence and geology marks), a multiple linear regression analysis was used. This analysis relies on the following three standard statistical tests:

- The F-test for overall model fit to verify whether all independent variables significantly explain the dependent variable;
- The t-test for regression coefficients to examine the statistical significance of each predictor's effect on the dependent variable;
- The coefficient of determination (adjusted R^2) to measure the proportion of variance in the dependent variable explained by the model.

These tests make it possible to determine the proportion of influence of each predictor on the dependent variable (Y), through the following regression equation: $Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + \varepsilon$.

All independent variables in this study were transformed into dummy variables for inclusion in linear regression using codes 0 and 1 [34, 35].

Gender was recorded as a *"female"* dichotomous variable with *"0"* for boys and *"1"* for girl.

The polytomous variables (school level, place of residence and geology marks) were coded using the *"K–1"* transformation method, which consists of creating a dummy variable for each category, while retaining a reference category.

All stages of the regression analysis were performed using SPSS software (version 27).

III. Results

In order to carry out the regression analysis, the classical assumptions (normality, multicollinearity, heteroscedasticity and linearity) were first verified.

The normality was assessed using a Quantile-Quantile plot (Q-Q plot). This method is widely used and effective in linear regression analysis [36]. The results obtained (see Appendix B) showed that, overall, the points aligned well on the diagonal, proving that the data followed a normal distribution.

The multicollinearity assumption, the results in Table 4 show that the tolerance and Variance Inflation Factor (VIF) values for each predictor are 0.1 higher and 3 lower, respectively. These results attest to the absence of problematic multicollinearity between the predictors.

Table 4. Multicollinearity test results

Predictors	Girl	1 YMS	2 YMS	3 YMS	CSC	1 BAC	Rural	Semi-Urban	Less than 10	Between 10 and 15
Tolerance	0.959	0.466	0.422	0.434	0.458	0.539	0.622	0.659	0.589	0.632
VIF	1.043	2.148	2.367	2.302	2.183	1.857	1.607	1.517	1.698	1.582

The assumption of heteroscedasticity was tested using the *Glejser test*. The analysis of the results obtained (see Table 5) reveals that the *p*-value of each predictor for the dependent variable is significant ($P > 0.05$), proving the absence of any sign of heteroscedasticity in the model.

Furthermore, Pearson's correlation test was also used to determine the best predictors of Moroccan students' motivation in geology before performing a regression analysis. The results (Table 6) show that the predictors with a strong correlation with motivation for geology were gender (girl) and students' performance in this subject (below 10), with respective correlation coefficients in absolute value: $0.047 < r < 0.122$ and $-0.345 < r < -0.147$.

The results of the analysis show that the classical assumptions of the regression model are satisfied. Therefore, we can now proceed to the analysis of the model predictors and assess the influence of each on the dependent variable.

Table 5. Results of the Glejser test

Dependent variables	*P*-value of independent variables									
	Girl	1 YMS	2 YMS	3 YMS	CSC	1 BAC	Rural	Semi-Urban	Less than 10	Between 10 and 15
Intrinsic Motivation	0.565	0.080	0.075	0.563	0.895	0.140	0.190	0.966	0.085	0.568
Self-Efficacy	0.750	0.061	0.052	0.056	0.211	0.051	0.749	0.276	0.060	0.058
Self-Determination	0.770	0.329	0.553	0.801	0.404	0.697	0.999	0.646	0.358	0.168
Grade Motivation	0.474	0.054	0.051	0.107	0.060	0.061	0.070	0.395	0.051	0.053
Career Motivation	0.522	0.190	0.061	0.267	0.416	0.377	0.081	0.173	0.185	0.257

Table 6. Pearson correlation test results on the dependent variables

Dependent variables	Correlation coefficient (r)									
	Girl	1 YMS	2 YMS	3 YMS	CSC	1 BAC	Rural	Semi-Urban	Less than 10	Between 10 and 15
Intrinsic Motivation	0.108**	–0.002	0.010	–0.060**	0.042	–0.006	0.013	–0.026	–0.208**	–0.023
Self-Efficacy	0.122**	–0.016	–0.052*	–0.153**	0.111**	0.040	–0.068**	–0.006	–0.345**	–0.040
Self-Determination	0.114**	0.103**	0.076**	–0.142**	0.051*	–0.046*	0.042	–0.044*	–0.211**	–0.026
Grade Motivation	0.084**	0.025	0.057*	–0.051*	–0.002	0.028	0.027	–0.043	–0.183**	–0.044*
Career Motivation	0.047*	0.141**	–0.032	–0.105**	0.018	–0.041	0.079**	–0.034	–0.147**	0.017

Note: *$p < 0.05$; **$p < 0.01$

A. The Regression Model

The results of the regression model calculation and the ANOVA for the effect of all predictors on the components of students' motivation to learn geology are summarized in Table 7.

The analysis of the results in Table 6 above, reveals a statistically significant relationship (p-value < 0.05) was found between the predictors and the components of students' motivation to learn geology in the Moroccan secondary cycle, with the proportion of variance explained by the model (adjusted R^2) ranging from 0.063 to 0.216. This indicates that this model explains only a small (6.3%) to moderate (21.6%) proportion of the variance in the components of students' motivation to learn geology. Given the inherent complexity of human behavior and the multiple factors that influence it, this model can be considered acceptable, but it simultaneously suggests that 78% of the other predictors significantly influencing geology students' motivation were not explored by this model.

Table 7. Summary of regression models and the Anova for all predictors of the geology motivation dimension

Dependent variables	Model summary			ANOVA		
	R	R^2	Adjusted R^2	F	df	*p*-value
Intrinsic Motivation	0.293	0.086	0.081	19.180	10	< 0.001
Self-Efficacy	0.469	0.220	0.216	57.688	10	< 0.001
Self-Determination	0.367	0.135	0.131	31.852	10	< 0.001
Grade Motivation	0.307	0.094	0.090	21.209	10	< 0.001
Career Motivation	0.259	0.067	0.063	14.681	10	< 0.001

As for the analysis of the regression coefficients (B), it allows for assessing the direction and magnitude of the individual effect of each predictor on the components of students' motivation to learn geology in Morocco. Table 8 shows the values of B.

Table 8. Regression coefficients of predictors on the students' motivation component in geology

Dependent Variables	Predictors	Coefficient				
		B	Standard error	β	T	*P*-value
Intrinsic Motivation (IM)	Constant	3.320	0.078	-	42.655	0.000
	Girl	0.141	0.041	0.075	3.492	0.000
	1 YMS	0.107	0.077	0.043	1.386	0.166
	2 YMS	0.142	0.076	0.061	1.878	0.060
	3 YMS	0.017	0.075	0.007	0.228	0.820
	CSC	0.047	0.075	0.020	0.627	0.531
	1BAC	–0.004	0.081	–0.002	–0.053	0.958
	Rural	0.087	0.051	0.046	1.721	0.085
	Semi-Urban	0.007	0.053	0.004	0.138	0.891
	Less than 10	–0.778	0.063	–0.342	–12.421	0.000
	Between 10 and 15	–0.415	0.050	–0.221	–8.290	0.000
Self-Efficacy (SE)	Constant	3.873	0.071	-	54.401	0.000
	Girl	0.103	0.037	0.055	2.776	0.006
	1 YMS	–0.036	0.071	–0.015	–0.508	0.611
	2 YMS	–0.054	0.069	–0.024	–0.785	0.433
	3 YMS	–0.261	0.069	–0.112	–3.784	0.000
	CSC	–0.020	0.068	–0.008	–0.293	0.769
	1BAC	–0.061	0.074	–0.022	–0.823	0.410
	Rural	–0.010	0.046	–0.005	–0.222	0.824
	Semi-Urban	–0.009	0.049	–0.004	–0.180	0.857
	Less than 10	–1.189	0.057	–0.528	–20.748	0.000

	Between 10 and 15	–0.652	0.046	–0.350	–14.232	0.000
Self-Determination (SD)	Constant	2.987	0.077	-	38.622	0.000
	Girl	0.184	0.040	0.096	4.580	0.000
	1 YMS	0.554	0.077	0.217	7.209	0.000
	2 YMS	0.487	0.075	0.205	6.489	0.000
	3 YMS	0.079	0.075	0.033	1.059	0.290
	CSC	0.270	0.074	0.111	3.644	0.000
	1BAC	0.105	0.081	0.036	1.294	0.196
	Rural	0.108	0.050	0.056	2.145	0.032
	Semi-Urban	0.012	0.053	0.006	0.231	0.818
	Less than 10	–0.859	0.062	–0.370	–13.797	0.000
	Between 10 and 15	–0.467	0.050	–0.243	–9.396	0.000
Grade Motivation (GM)	Constant	3.705	0.077	-	48.296	0.000
	Girl	0.107	0.040	0.058	2.679	0.007
	1 YMS	0.379	0.076	0.153	4.965	0.000
	2 YMS	0.444	0.074	0.193	5.968	0.000
	3 YMS	0.255	0.074	0.110	3.434	0.001
	CSC	0.176	0.073	0.075	2.399	0.017
	1BAC	0.296	0.080	0.106	3.695	0.000
	Rural	0.063	0.050	0.034	1.266	0.206
	Semi-Urban	–0.036	0.053	–0.018	–0.677	0.498
	Less than 10	–0.796	0.062	–0.354	–12.893	0.000
	Between 10 and 15	–0.463	0.049	–0.249	–9.382	0.000
Career Motivation (CM)	Constant	2.847	0.092	-	31.109	0.000
	Girl	0.095	0.048	0.043	1.993	0.046
	1 YMS	0.354	0.091	0.122	3.894	0.000
	2 YMS	–0.060	0.089	–0.022	–0.672	0.502
	3 YMS	–0.184	0.089	–0.067	–2.073	0.038
	CSC	–0.006	0.088	–0.002	–0.074	0.941
	1BAC	–0.137	0.096	–0.042	–1.436	0.151
	Rural	0.263	0.059	0.120	4.425	0.000
	Semi-Urban	0.093	0.063	0.039	1.475	0.140
	Less than 10	–0.582	0.074	–0.220	–7.901	0.000
	Between 10 and 15	–0.258	0.059	–0.118	–4.387	0.000

Based on the analysis of the regression results presented in Table 8, and considering the statistical significance threshold ($P < 0.05$) as well as the predefined reference categories (male gender, 2BAC school level, urban residence, and marks > 15), the results indicate that the set of predictors does not have a significant influence across all motivational components (IM, SE, SD, GM, and CM) among Moroccan students in geology. However, certain trends are worth highlighting:

Intrinsic Motivation (IM) is positively associated with female gender (B = 0.141). However, it is significantly lower among students who obtained average marks below 10 (B = –0.778) or between 10 and 15 (B = –0.415), compared to those who scored above 15.

Self-Efficacy (SE) is also positively associated with female gender, although the effect remains weak (B = 0.103). A negative effect was also observed among 3YMS students (B = –0.261) and those who scored below 10 (B = –1.189) or between 10 and 15 (B = –0.652), compared to the reference categories.

Self-Determination (SD) is positively influenced by female gender, several school levels prior to the 2BAC (1 YMS, 2 YMS, and CSC), as well as by rural residence (B = 0.108). However, low marks (below 10) or average marks (between 10 and 15) are associated with a significant decrease in self-determination among Moroccan students in geology.

Grade Motivation (GM) is positively influenced by female gender as well as by all the school levels examined (1YMS, 2YMS, 3YMS, CSC, and 1BAC). In contrast, students with low or average marks show significantly lower grade motivation compared to those who scored above 15.

Career Motivation (CM) is positively associated with female gender (B = 0.095), 1 YMS school level (B = 0.354), and rural residence (B = 0.263), while it is negatively associated with 3 YMS school level (B = –0.184). As with all other motivational components, low or average marks in geology are systematically associated with a significant decrease in career motivation compared to students who scored above 15.

B. Analysis of Qualitative Data

The maximum value for the proportion of influence of the proposed regression model is 22%. This indicates that 78% of the other predictors were not taken into account by this model. To identify these missing factors, we transcribed and coded the qualitative interviews, then analyzed the discourse thematically (see Table 9 for coding details).

This combined approach provides a more comprehensive understanding of the determinants of motivation in geology.

The analysis of the results of interviews conducted with 26 students helped to enrich the quantitative results, identifying six other factors influencing students' motivation to learn geology in secondary school:

1) The socio-familial environment

A total of 73.1% of the students surveyed highlighted the influence of their socio-familial environment on their motivation to learn geology. They mentioned in particular the importance of their parents' support, the influence of their peers, but also the difficult economic situation and cultural level of their parents, as well as the professional careers of their relatives in the field of geology.

Table 9. Summary of coding for other factors influencing student motivation in geology

Factors	Some key aspects extracted	Percentage
Socio-familial environment	-Parental support and peer impact, -Parents' economic status and cultural level -Family career in geology.	73.10% (N = 19)
Past experience	-Negative experience with teacher and/or subject. -Interesting extra-curricular experiences.	34.61% (N = 9)
Impact of the teacher and the quality of teaching practices	-Lack of empiricism (laboratory experiments and field trips). -Traditional teaching methods and styles. -Teacher dominance in the construction of knowledge. -Student-teacher interaction.	96.15% (N =25)
Digital literacy	-Digital tools: *computers, platforms, YouTube videos, etc.* -Technological tools: *artificial intelligence applications, electronic whiteboards, Internet videos, etc.*	46.16% (N = 12)
Geological concepts taught	-Geological concepts too difficult. -Factor of abstraction (spatiotemporal). -Decontextualization of geological concepts.	100% (N = 26)
Organizational and educational aspects	-Language of instruction. -Time spent on the session. -Timing of lessons.	42.30% (N = 11)

2) The previous experiences

34.61% of students also mentioned the influence of their personal experiences and teachers on their motivation. Some of them attributed their lack of interest and motivation in learning geology to the attitude of certain teachers, particularly due to their behavior, which was marked by exclusion and discrimination in the classroom. Other students praised the decisive role of extracurricular activities in strengthening their motivation and commitment to learning geology.

3) The quality of teaching practices

An overwhelming majority of students (96.15%) highlighted the complete absence of empirical approaches and the ineffectiveness of the teaching methods used in class. They emphasized that this had a negative impact not only on their understanding of the geological content taught, but also on their motivation to learn this subject. Only a tiny minority mentioned that enthusiasm, encouragement, and the ability of teachers to demonstrate the economic and scientific importance of geology were determining factors in their motivation to learn this subject.

4) The digital literacy

A total of 46.16% of students reported that the use of technological and digital tools (artificial intelligence, platforms, internet, etc.) has a positive influence on their motivation to learn the subject, as these tools help them understand lessons and do their homework, and allow them to easily access information.

5) The complexity of the geological concepts taught

The students surveyed unanimously expressed difficulty understanding the geological phenomena taught, due to the complexity of the concepts covered and the succession of geological events over a very long period of time and in three-dimensional space, which reduced their motivation to learn this subject.

6) The organizational and educational aspects of the programs taught

A total of 42.30% of the students surveyed stated that teaching geology in French had hindered their understanding and progress, due to language barriers and technical vocabulary. Some middle school students pointed out that allocating two hours to each class session leads to boredom and reduces their ability to concentrate. High school students also expressed dissatisfaction with how geology classes are scheduled and timed in the 1BAC and 2BAC programs.

IV. Discussion

The aim of this study was to identify the factors influencing the motivation of Moroccan secondary school geology students. To this end, we collected both quantitative and qualitative data from students using a mixed methodology combining a questionnaire (GMQ-II) and semi-structured interviews.

The GMQ-II data were analyzed using multiple regression analysis. This analysis revealed that the four predictors examined (gender, school level, place of residence and geology marks) had no significant overall effect on motivation, as evidenced by the low coefficient of determination adjusted R^2 (see Table 7). Contrary to several previous scientific studies [16, 37, 38], which confirmed gender as the best predictor variable, geology marks had the highest absolute correlation value in this study.

The marks below 10 were negatively and highly significantly correlated with all dimensions of student motivation in geology, in particular with intrinsic motivation, self-efficacy and self-determination. Marks between 10 and 15 showed negative, non-significant correlations, indicating that although students scored slightly higher in geology, their motivation to learn the subject remained low. Overall, these results suggest that students with low geology marks are less motivated than those with slightly higher marks. This finding is in line with several scientific studies [2, 4, 5, 23], which have confirmed that good grades can enhance students' motivation and engagement in their scientific learning, and vice versa.

The results of the correlation analysis indicate that gender has a slightly weak effect on the motivation of Moroccan secondary school students to learn geology. This finding is in line with the conclusions of several scientific studies conducted on motivation [16, 21, 38].

The positive and highly significant correlations observed with all the dimensions of motivation suggest that girls are globally more motivated than boys to learn geology, and this is particularly true with regard to self-efficacy and self-determination. These results confirm the findings of several previous studies conducted on motivation in science learning [16, 23, 38]. The interviews with students revealed that: *"girls showed a higher degree of perseverance and seriousness, placed more importance on school success and scientific careers, and showed a greater commitment to scientific subjects than boys"*, factors that could explain the differences in motivation between the two genders.

The Class differences were considered predictive variables in this study, but had no statistically significant effect on Moroccan students' motivation to learn geology. This finding is consistent with that of the study conducted by Huda and Rohaeti [38], who found that Chinese students' class differences had a weak effect on their motivation in chemistry. The transcripts of interviews with the students also confirmed this conclusion: *none of them mentioned that progression through the school levels had any influence on their motivation to learn geology*. Although statistical results show that class differences do not have significant and consistent effects, a general trend shows that motivation decreases as students progress through school. This observation is also corroborated by several didactic works on motivation in science [14, 15, 23, 38].

The place of residence was also a predictor variable examined in this study (Rural, Semi-urban and Urban). The results of the correlation coefficient analysis show a very low value, suggesting that differences in place of residence have no statistically significant effect on Moroccan students' motivation to learn geology. The interviews conducted also confirmed this conclusion: *none of the students mentioned the influence of their area of residence on their motivation to learn geology*. The lack of effect of differences in residence on students' motivation in geology can be explained by different but complementary environments: urban areas are characterized by greater access to educational resources and more favorable study conditions, which promote scientific learning, while rural and semi-urban areas are characterized by geological heritage that allows students to enrich their scientific thinking and motivate them to learn this subject. In line with these results, Zhang and Zhou [16] also found no significant difference in the motivation of secondary school students, whether urban or rural, to learn chemistry.

The analysis of the regression model results revealed that the statistical effects of the predictors examined did not apply to all components of motivation, with the exception of gender (female) and student performance in geology (below 10 or between 10 and 15), which appeared repeatedly in the various equations. These results suggest that gender and performance play a decisive and significant role in explaining differences in Moroccan students' motivation to learn geology.

More specifically, gender (female) proved to be the most significant predictive variable, promoting all dimensions of student motivation in geology, particularly self-determination. These results are consistent with the findings of previous scientific studies [21, 23, 38], which confirmed that girls were more motivated and self-determined than boys in science learning. This finding was also supported during the interviews, in which girls showed higher motivation than boys for learning geology, due to the scientific importance of the subject, the professional and academic careers associated with it, as well as their spirit of scientific discovery and interest in science. This trend is well illustrated by the following comments from a female student: *"I really enjoy science subjects, especially geology, because it allows us to explain the natural phenomena around us and understand how the Earth works. In addition, I would like to become a teacher of this subject, like my mother, or a mining engineer."*

Performance differences (marks below 10) had the most significant, but negative, effects on all components of student motivation, with regression coefficients (b) ranging from −1.189 to −0.582. Performance in geology is therefore the predictive factor that most reduces student motivation, particularly the components of self-determination and self-efficacy. These results were strikingly confirmed by the students during interviews. Five of them indicated that their lack of motivation was due to their poor performance in geology, as evidenced by the following comment from a student: *"In my first year of middle school, I was passionate about the subject and got good results. But when I moved up to the second year, my marks dropped dramatically, despite all my efforts to study. This frustrated me and reduced my motivation to learn the subject."*

Differences in school level and place of residence do not have a systematically significant effect on all aspects of student motivation in geology. Only grade motivation shows a positive influence linked to class differences. As for place of residence, only rural students show a positive influence, specifically on the dimensions of self-determination and career motivation. Overall, the effects of school progress and place of residence on students' motivation, although present, remain very limited.

Overall, the proposed regression model explained only 21.6% of the total proportion of predictive variables for motivation in geology. Other factors were extracted from the transcripts of interviews conducted with students, including the socio-familial environment, students' previous experiences with the subject, the quality of teaching practices in the classroom, digital literacy, the complexity of geological concepts, and the organizational and educational aspects of the programs taught. Aware that motivation is an overly complex affective concept in humans, which can be influenced by numerous subjective and/or objective factors when learning geology, this study remains relevant but needs to be supplemented by further scientific research to identify other potential factors influencing motivation in geology, with the aim of making the learning of this subject more appealing and improving the quality of teaching practices.

V. Conclusion and Recommendations

This study aimed to identify the factors influencing Moroccan secondary school students' motivation to learn geology. To achieve this objective, a rigorous

methodological approach involving four distinct steps was adopted:

- **Review of existing literature:** An in-depth analysis of previous scientific work on motivation was carried out, accompanied by the choice of a mixed research methodology combining quantitative (GMQ-II) and qualitative (semi-structured interviews) approaches.
- **Data collection:** The data were collected from a representative sample of secondary school students in the Marrakech-Safi region (Morocco).
- **Data analysis:** The quantitative data were analyzed using multiple linear regression tests, while the qualitative data were analyzed using content analysis.
- **Interpretation of results:** The results obtained were interpreted in light of the research objectives set, then compared with data from the existing literature.

The results of this study showed that gender was the predictive variable with the most significant impact on all aspects of student motivation. Girls are more motivated than boys to learn geology.

The differences in marks obtained in geology also have a significant, but negative, effect on all components of students' motivation, particularly self-efficacy and self-determination. In fact, the lower the results in geology, the lower the level of motivation tends to be, and conversely.

The results show that differences in school level do not have significant and consistent effects on all components of student motivation in geology, with the exception of the 3 YMS class, which has a significant and consistent, but negative effect on all aspects of student motivation, particularly self-efficacy and career motivation. However, a general trend shows that motivation decreases as students progress through school.

As for the differences in students' places of residence, their influence proved to be the weakest among all the predictive variables examined, and even almost negligible. This highlights that differences in place of residence are not a significant determinant of students' motivation in geology, and that it would therefore be irrelevant to consider them as a motivating factor for learning geology in future studies in Morocco.

Finally, it should be emphasized that the regression model explains only 22% of the total variables predicting students' motivation in geology, while qualitative interviews with 26 students identified six other factors influencing motivation: *socio-familial environment, previous experiences, quality of teaching practices, digital literacy, complexity of geological concepts, and organizational and educational aspects of the programs taught*.

The results of this study offer several avenues for reflection and recommendations for both future research and teaching practices aimed at increasing Moroccan students' motivation in geology and making its learning more captivating and engaging.

A. Recommendations for Future Research

The results of this study highlight the need for further research into Moroccan students' motivation to learn geology. To this end, the sample should be expanded to include all regions of the country, and the different demographic characteristics of the students should be taken into account in order to gain a more complete understanding of the factors influencing motivation in geology. It is also recommended that a mixed methodological approach of the sequential explanatory type be adopted to analyze student motivation in greater depth, explore their subjective experiences, and understand their psychosocial backgrounds.

Furthermore, to better account for the correlations among the different motivational dimensions and to reduce the risk of Type I error, future research should employ multivariate methods, such as multivariate multiple regression or MANOVA/MANCOVA analyses. These approaches would help produce more robust and interpretable results, providing detailed data to support the improvement of geology instruction quality.

In addition, the factors identified through the interviews conducted in this study deserve to be examined in future research as predictive variables of motivation, using advanced statistical analyses (correlation and multiple regression tests, etc.), in order to better explain students' motivation in geology.

B. Practical Recommendations of the Findings

The results of the study highlight the need to take into account the affective and psychological aspects of students in the teaching of geology, by offering them psychological support programs to improve their mental well-being and motivation to learn the subject. It is also advisable to organize training sessions in educational psychology for geology teachers, to enable them to develop their skills in educational communication techniques and emotion management.

In addition, geology teaching should be adapted to gender differences, in particular by encouraging boys to participate more actively in learning activities and competitive dynamics. It is also necessary to improve the conditions for teaching geology in rural areas, in particular by equipping science laboratories with modern technology to encourage experimentation and interaction with geological phenomena.

The study also revealed that marks had an impact on motivation to learn, which means that additional educational support programs need to be offered to students who perform poorly in geology. These programs may include targeted interactive activities, as well as individual or group sessions supervised by teachers, in order to optimize these students' motivation to learn geology.

Finally, family support for students in their studies and the creation of channels of communication between parents and the school are essential, as the results of this study show.

APPENDIX: RESULTS OF CONFIRMATORY FACTOR ANALYSIS AND NORMALITY ASSESSMENT (Q-Q PLOTS)

A. Confirmatory Factor Analysis

Fig. A1. presents the standardized factor loadings and the correlations among the factors estimated by AMOS.

B. Quantile-Quantile Plots (Q-Q Plots)

Figs. A2–6 show the results of the Q-Q Plots used to verify the normality of the data distribution for each of the five motivational components.

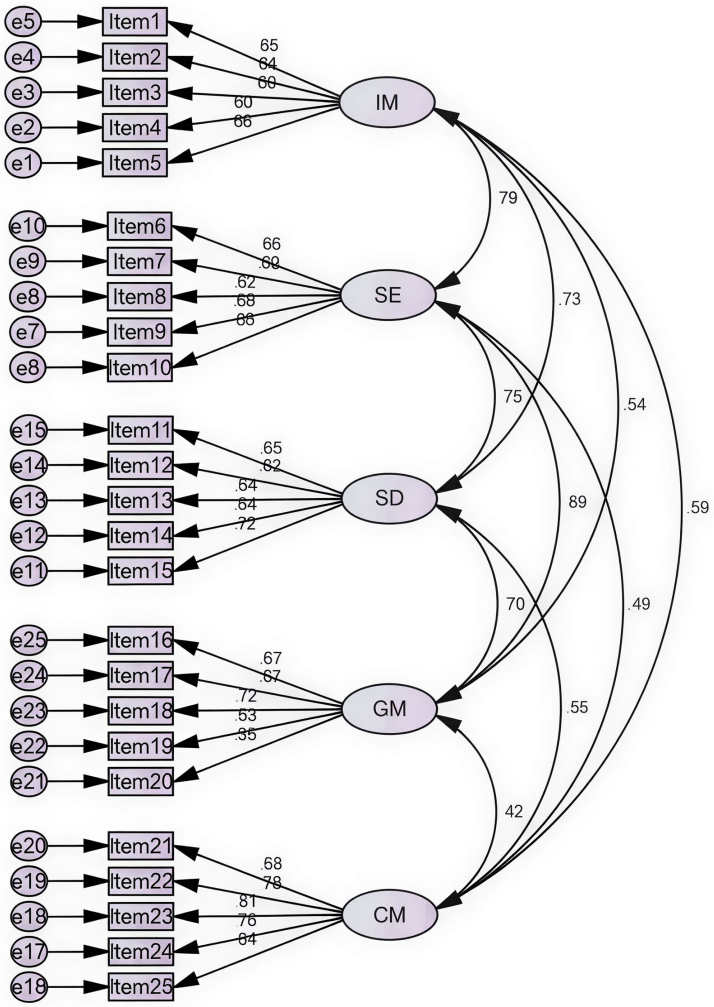

Fig. A1. Confirmatory factor analysis: Standardized factor loadings and correlations. IM, intrinsic motivation; CM, career motivation; SD, self-determination; SE, self-efficacy; GM, grade motivation; e, error term.

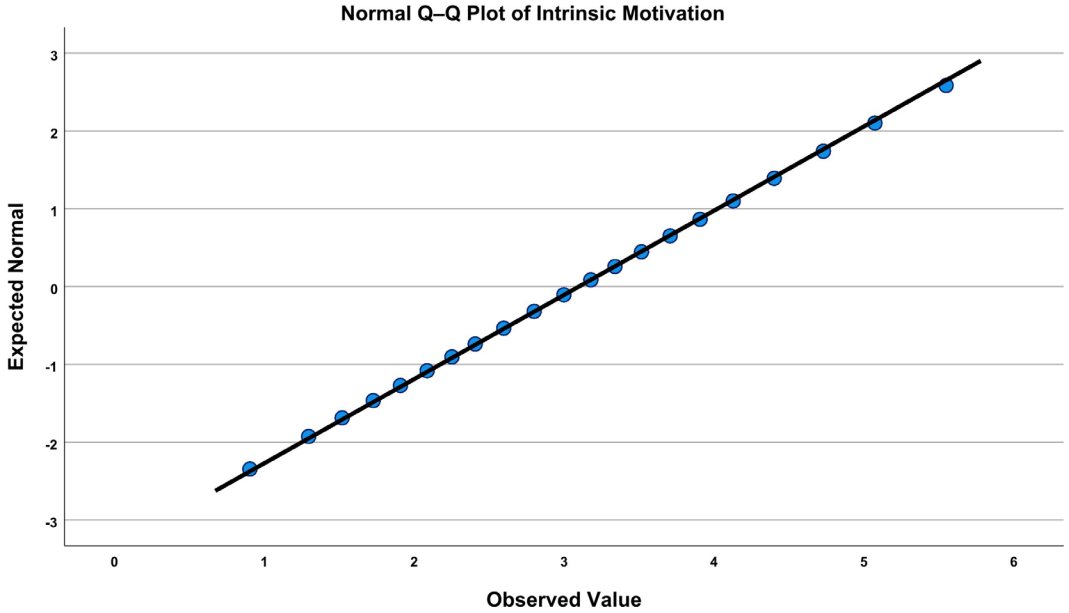

Fig. A2. Q-Q plot of intrinsic motivation.

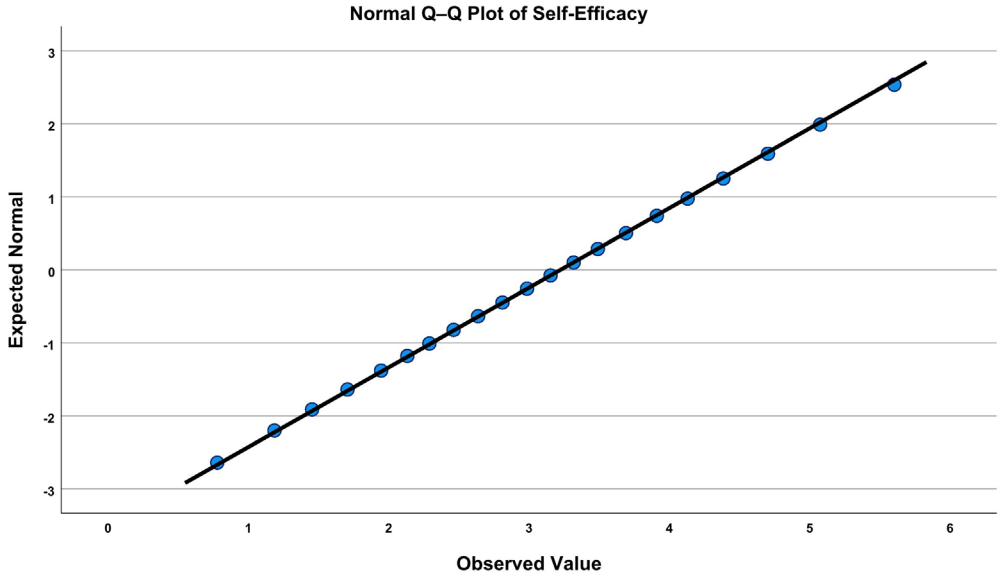

Fig. A3. Q-Q plot of self-efficacy.

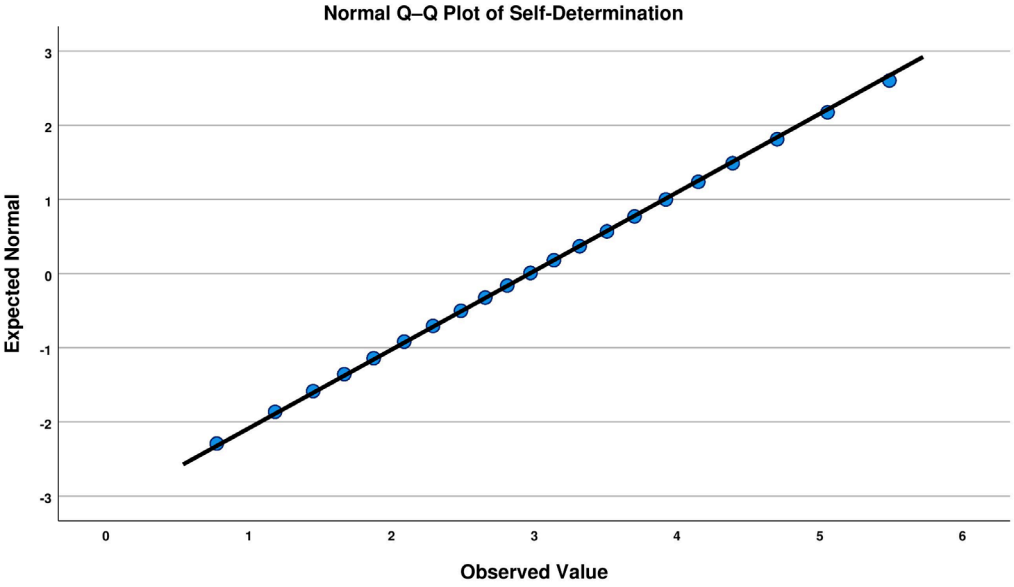

Fig. A4. Q-Q plot of self-determination.

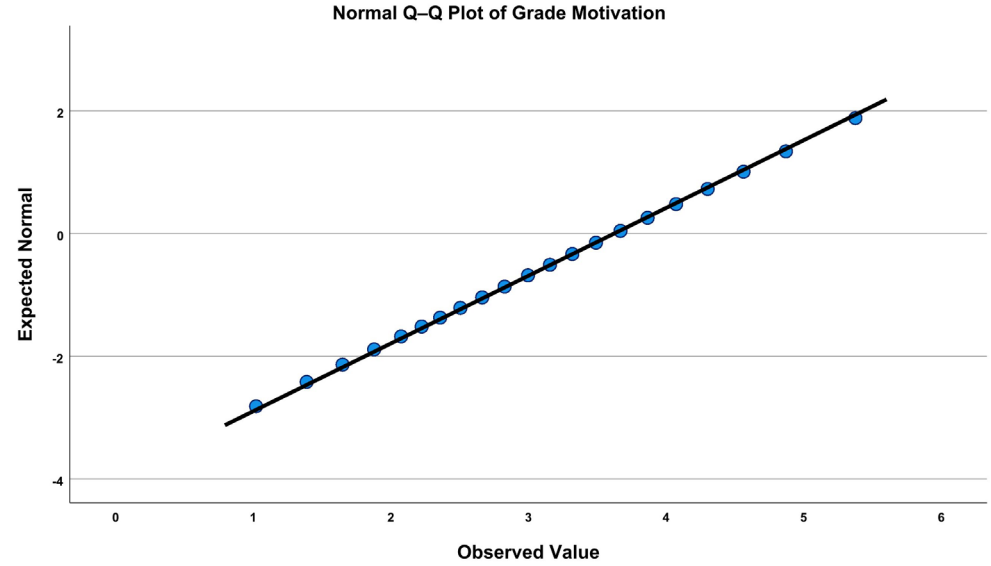

Fig. A5. Q-Q plot of grade motivation.

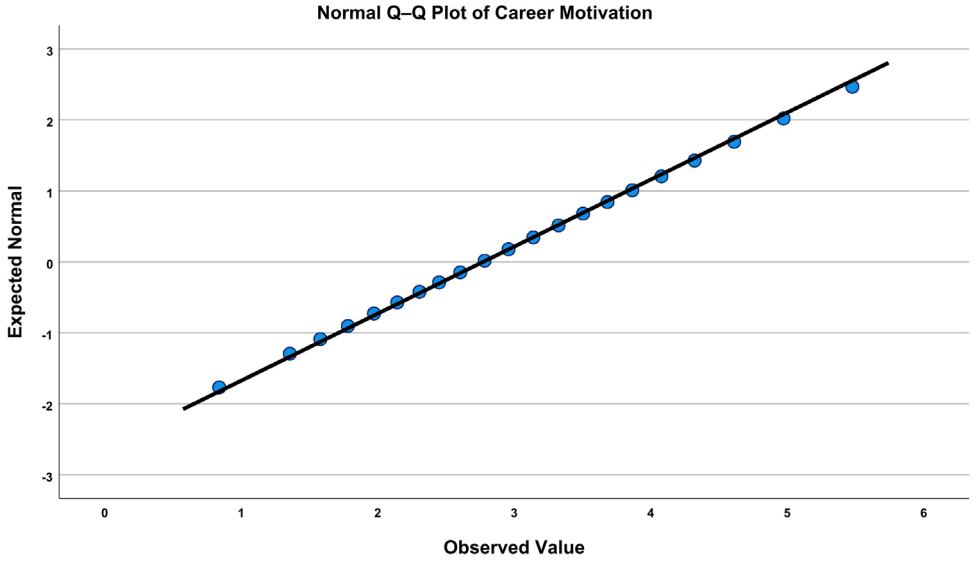

Fig. A6. Q-Q plot of career motivation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Mohammed El Moudden: Admin, Conceptualization, design, analysis, writing—original draft; Saïd Chakiri: supervision, final approval; Mohamed Yazidi: Editing/reviewing, supervision, final approval; El Mostapha Bouhamid and Bouchra Jaima: data acquisition; Omar Amahmid and Bouchra Razoki: critical revision of manuscript, final approval. All authors have read and approved the final version of the manuscript.

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REFERENCES

[1] E. E. A. Marpaung, "The relationship between learning motivation and learning facility conditions with learning achievement in online learning: A case study of economic education students BKK accounting education, Sanata Dharma University," Undergraduate thesis, Sanata Dharma University, Sanata Dharma University Repository, October 2021.

[2] M. Salih, M. Y. Mai, and A. Shibli, "Students' motivation toward science learning in secondary schools in Oman and Malaysia: A comparative study," *Journal of Research, Policy & Practice of Teachers and Teacher Education*, vol. 6, no. 1, pp. 16–24, June 2016.

[3] M. Teppo, R. Soobard, and M. Rannikmäe, "A study comparing intrinsic motivation and opinions on learning science (Grades 6) and taking the international PISA test (Grade 9)," *Education Sciences*, vol. 11, no. 1, pp. 1–18, 2021. doi: 10.3390/educsci11010014

[4] P. I. Raysharie, L. T. Harinie, N. Inglesia, Vita, S. Wati, B. Sianipar, Ongki, R. Pasha, M. Abdurrahman, K. A. Fadilla, and F. Putri, "The effect of student's motivation on academic achievement," *Journal Pendidikan Ilmu Pengetahuan Sosial*, vol. 15, no. 1, pp. 168–175, June 2023. doi: 10.37304/jpips.v15i1.9552

[5] E. Satrianti, O. D. Pranata, and T. Tiara, "Science learning motivation among students at junior and senior high schools in Sungai Penuh: A comparative study," *Jurnal Pijar Mipa*, vol. 19, no. 1, pp. 20–26, January 2024. doi: 10.29303/jpm.v19i1.6101

[6] S. Lau and R.W. Roeser, "Cognitive abilities and motivational processes in high school students' situational engagement and achievement in science," *Educational Assessment*, vol. 8, no. 2, pp. 13–162, June 2002. doi: 10.1207/S15326977EA0802_04

[7] D. Ardura and A. Pérez-Bitrián, "The effect of motivation on the choice of chemistry in secondary schools: Adaptation and validation of the Science Motivation Questionnaire II to Spanish students," *Chemistry Education Research and Practice*, vol. 19, no. 3, pp. 905–918, May 2018. doi: 10.1039/c8rp00098k

[8] I. Plante, P. A. O'Keefe, and M. Théorêt, "The relation between achievement goal and expectancy value theories in predicting achievement related outcomes: A test of four theoretical conceptions," *Motivation and Emotion*, vol. 37, no. 1, pp. 65–78, March 2013. doi: 10.1007/s11031-012-9282-9

[9] A. D. Nuraysha, N. Winarno, W. Fadly, L. Hakim, and E. Emiliannur, "Analyzing student's motivation towards science learning in junior high school," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 7, pp. 4139–4148, July 2024. doi: 10.29303/jppipa.v10i7.7297

[10] D. Ardura, Á. Zamora, and A. Pérez-Bitrián, "The role of motivation on secondary school students' causal attributions to choose or abandon chemistry," *Chemistry Education Research and Practice*, vol. 22, no. 1, pp. 43–61, Aug. 2021. doi: 10.1039/D0RP00168F

[11] M. E. King-Sears and V. Strogilos, "An exploratory study of self-efficacy, school belongingness, and co-teaching perspectives from middle school students and teachers in a mathematics co-taught classroom," *International Journal of Inclusive Education*, vol. 24, no. 2, pp. 162–180, April 2018. doi: 10.1080/13603116.2018.1453553

[12] E. L. Deci and R. M. Ryan, "The 'What' and 'Why' of goal pursuits: Human needs and the self-determination of behavior," *Psychological Inquiry*, vol. 11, no. 4, pp. 227–268, November 2000. doi: 10.1207/S15327965PLI1104_01

[13] K. R. Wentzel, and A. Wigfield, *Handbook of Motivation at School*, 1st ed. September 2009. doi: 10.4324/9780203879498

[14] S. B. Chumbley, J. C. Haynes, and K. A. Stofer, "A measure of students' motivation to learn science through agricultural STEM emphasis," *Journal of Agricultural Education*, vol. 56, no. 4, pp. 107–122, December 2015. doi: 10.5032/jae.2015.04107

[15] G. Molnár and Z. Hermann, "Short- and long-term effects of Covid-related kindergarten and school closures on first- to eighth-grade students' school readiness skills and mathematics, reading and science learning," *Learning and Instruction*, vol. 83, 101706, February 2023. doi: 10.1016/j.learninstruc.2022.101706

[16] J. Zhang and Q. Zhou, "Chinese chemistry motivation questionnaire II: Adaptation and validation of the science motivation questionnaire II in upper-secondary students," *Chemistry Education Research and Practice*, vol. 24, no. 1, pp. 369–383, January 2023. doi: 10.1039/D2RP00243D

[17] S. Benzer, Y. Sarisik, and H. Kocan, "Factors affecting the motivation levels of secondary school students for science learning," *Special Topics in Science Education Research,* pp. 117–129, 2020.

[18] A. Bandura, *Social Foundations of Thought and Action: A Social Cognitive Theory, Englewood Cliffs*, NJ: Prentice-Hall, 1986.

[19] A. Bandura, "Social cognitive theory: An agentic perspective," *Annual Review of Psychology*, vol. 52, no. 1, pp. 1–26, February 2001. doi: 10.1146/annurev.psych.52.1.1

[20] A. Bandura, "Going global with social cognitive theory: From prospect to paydirt," in *The Rise of Applied Psychology: New Frontiers and Rewarding Careers*, S. I. Donaldson, D. E. Berger, K. Pezdek, Eds. Mahwah, NJ: Erlbaum, pp. 53–70, 2006.

[21] S. M. Glynn, P. Brickman, N. Armstrong, and G. Taasoobshirazi, "Science motivation questionnaire II: Validation with science majors and nonscience majors," *Journal of Research in Science Teaching*, vol. 48, no. 10, pp. 1159–1176, September 2011. doi: 10.1002/tea.20442

[22] J. Mazlo, D. Dormedy, J. Niemoth-Anderson, T. Urlacher, G. Carson, E. Haas, and P. Kelter, "What motivates students in the lab? Assessing motivational methods in the general chemistry lab," *Journal of College Science Teaching*, vol. 31, no. 5, pp. 318–321, February 2002.

[23] M. El Moudden, S. Chakiri, M. Yazidi, E. M. Bouhamid, H. Itouni, B. Razoki, and O. Amahmid, "Moroccan students' motivation to learn geology in secondary school: A cross-sectional survey," *Multidisciplinary Science Journal*, vol. 8, no. 2, 2026040, August 2025. doi: 10.31893/multiscience.2026040

[24] A. Lakhloufi, *Why Did the Study of Geology Not Succeed in Morocco?* The Press Week (Alousboua Assahafi), Center for Studies and Research in Evaluation, Education, and Training, Mar. 26, 2014.

[25] E. Assimi, L. E. Nhili, K. Najoui, M. E. Qryefy, Y. Rakibi, R. Zerhane, and R. J. Idrissi, "Innovative approach for teaching and learning sciences through augmented reality," *International Journal on Technical and Physical Problems of Engineering (IJTPE),* vol. 16, no. 2, pp. 313–320, June 2024.

[26] A. Sayad, L. Boutkhil, A. Bouali, and F. El Miskine, "Obstacles to the teaching of earth sciences in Moroccan secondary schools," *Arabian Journal of Earth Sciences*, vol. 1, no. 4, pp. 1–15, July 2014.

[27] I. Chmanti-Houari, M. Oudrhiri-Hassani, H. Lachkhem, and A. Sayad, "Causes of the reluctance of Moroccan students towards geology: Case of the Faculty of Sciences Dharmahraz of Fez," *European Scientific Journal*, vol. 12, no. 1, pp. 220–226, January 2016. doi: 10.19044/esj.2016.v12n1p220

[28] K. Kaid-Rassou, F. Khiri, M. Benbrahim, Y. Tamraoui, H. Elberrani, and M. Anfour, "Difficulties relating to the teaching-learning of geology in qualifying secondary classes: Case of the Inzegane Ait Melloul Delegation," *European Scientific Journal*, vol. 13, no. 18, pp. 294–331, June 2017. doi: 10.19044/esj.2017.v13n18p294

[29] R. Chakour, A. Alami, S. Selmaoui, A. Eddif, and H. Chalak, "Conceptions of Moroccan secondary school students in relation to the 'integrative concept' of plate tectonics," *International Journal of Evaluation and Research in Education*, vol. 11, no. 4, pp. 2095–2105, December 2022. doi: 10.11591/ijere.v11i4.21861

[30] R. Chakour, A. Alami, S. Selmaoui, A. Eddif, M. Zaki, and Y. Boughanmi, "Earth sciences teaching difficulties in secondary school: A teacher's point of view," *Education Sciences*, vol. 9, no. 3, 243, September 2019. doi: 10.3390/educsci9030243

[31] B. G. Tabachnick and L. S. Fidell, *Using Multivariate Statistics*, 4th ed. Boston, MA: Allyn & Bacon, 2000

[32] D. George and P. Mallery, *SPSS for Windows Step by Step: A Simple Guide and Reference, 11.0 Update*, 4th ed. Allyn & Bacon, Boston, USA, May 2003.

[33] H. Noble and J. Smith, "Issues of validity and reliability in qualitative research," *Evidence Based Nursing*, vol. 18, no. 2, pp. 34–35, April 2015. doi: 10.1136/eb-2015-102054

[34] B. G. Tabachnick and L.S. Fidell, *Using Multivariate Statistics*, 6th ed. Pearson Education, June 2013.

[35] I. Ghozali, *Multivariate Analysis Applications with IBM SPSS 26 Program*, 10th ed. Diponegoro University Publishing Agency, June 2021. (in Indonesian)

[36] K. Huang, M. Qiao, X. Liu, S. Liu, and M. Dai, "Computer vision and metrics learning for hypothesis testing: An application of Q-Q plot for normality test," arXiv preprint, arXiv:1901.07851v2, September 2019.

[37] R. T. M. P. de Souza, M. D. S. B. da Silva, D. M. L. Barbato, M. E. R. de Guzzi, and A. C. Kasseboehmer, "Motivation to learn chemistry: A thorough analysis of the CMQ-II within the Brazilian context," *Chemistry Education Research and Practice*, vol. 23, no. 4, pp. 799–810, October 2022. doi: 10.1039/D2RP00107A

[38] N. Huda and E. Rohaeti, "The factors that influence the motivation to learn chemistry of upper-secondary school students in Indonesia," *Journal of Baltic Science Education*, vol. 22, no. 4, pp. 615–630, August 2023. doi: 10.33225/jbse/23.22.615