# EXPLORING FACTORS THAT AFFECT UNDERGRADUATE STUDENTS' MOTIVATION TO LEARN CHEMISTRY AND PHYSICS

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**Abstract.** *The pivotal role of motivation in fostering science learning has long been recognized and it is a field of active research worldwide. This research aimed at examining the effect of three different factors (used as independent variables) on shaping the motivation of undergraduate students for chemistry and physics learning via multiple regression analysis. Motivation (dependent variable) was measured via the use of the chemistry and physics-specific versions of Science Motivation Questionnaire II (SMQ II). The participants were 281 full-time undergraduate students in three different academic departments of a Greek tertiary education institution. Students' gender was shown to exert an effect of small size on their motivation for chemistry and physics learning, while a larger, however mostly small effect, was observed with regard to the students' academic major. Students' academic experience from the attendance of physics and chemistry courses was measured via an instrument which was developed specifically for this research, and it was shown to be the most influential factor affecting their respective learning motivations. In addition, strong evidence was provided that the academic experiences acquired during tertiary education have a significantly more intense effect in configuring students' motivation to learn either chemistry or physics relative to the ones obtained in the immediate past referring to the previous educational grade (secondary education).*
**Keywords:** *academic major, gender effect, quantitative research, science learning, students' experiences*

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## Introduction

The role of the affective component in science learning is a field of active research worldwide. More specifically, the importance of motivation to learn science has been widely recognized by the academic community and various theoretical perspectives have been developed to guide educational research (Koballa & Glynn, 2007). Social cognitive theory conceptualizes motivation to learn as a multidimensional construct which emerges from the interaction between personal, behavioral, and social/environmental factors (Bandura, 2001). More specifically, motivation components such as self-efficacy, self-determination, intrinsic motivation, career motivation and grade motivation, linked to science learning, have been extensively studied and reviewed (Bryan et al., 2011; Glynn et al., 2011; Koballa & Glynn, 2007; Pintrich, 2003; Salta & Koulougliotis, 2015; 2020).

According to the social cognitive perspective, students form their motivational structure by construing information from their school environment (among other sources) and there is evidence for the effect of several school features in students' motivation to learn science (Ardura et al., 2021). Among school features, students' sense of previous performance in science tasks and activities (mastery experience) significantly predicts their science self-efficacy (e.g., Britner & Pajares, 2006); students' sense of their science teacher, the school's specific goals, purposes and values also seem to play a significant role in students' motivation to learn science (e.g., Vedder-Weiss & Fortus, 2013). However, there is a need for understanding how students' motivational structures are shaped within different contextual and cultural practices (Ardura et al., 2021; Pintrich, 2003; Salta & Koulougliotis, 2020).

The domain specificity of motivational components across specific science disciplines (chemistry and physics) has been a topic of interest in recent years (e.g., Salta & Koulougliotis, 2020; Simpkins et al., 2015). Research in science education has provided evidence that self-efficacy (Dou et al., 2016; Ferrell et al. 2016; 2020; Nissen & Shemwell, 2016; Salta



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& Koulougliotis, 2020; Stoeckel, & Roehrig, 2021), intrinsic motivation, (Liu et al., 2017; Salta & Koulougliotis, 2020), self-determination (Salta & Koulougliotis, 2020), and extrinsic motivation, as well as grade motivation and career motivation, (Ardura & Pérez-Bitrián, 2018; Salta & Koulougliotis, 2020) are domain-specific motivational components.

Previous research has revealed the effect of various factors, such as gender, academic major, school features, parental supports, on students' motivation to learn various STEM disciplines (e.g., Cwik & Singh, 2021; Glynn et al., 2011, Nissen & Shemwell, 2016; Salta & Koulougliotis, 2015; 2020; Vedder-Weiss & Fortus, 2013). With respect to the academic major, previous research has provided evidence for differential motivation characteristics among science and non-science majors (Glynn et al., 2011). The study of the effect of gender on students' motivation has provided mixed results. Although, a gender gap favoring men in self-efficacy has been observed in physics courses (Cwik & Singh, 2021), a weak gender effect favoring women on intrinsic motivation for chemistry learning has been reported (Salta & Koulougliotis, 2020). Moreover, females are shown to exceed males regarding self-determination (Glynn et al., 2011; Salta & Koulougliotis, 2015; Schumm & Bogner, 2016).

The social cognitive perspective also proposes that students form their motivational perceptions by interpreting experience from their school environment, which includes the effect of the teacher, the school's specific goals, purposes and values, students' performance in tasks and activities and their perceptions of them (e.g., Britner & Pajares, 2006; Vedder-Weiss & Fortus, 2013). Students' mastery experiences are considered as the main source for the development of self-efficacy beliefs (Britner & Pajares, 2006; Capa-Aydin et al., 2018; Stoeckel & Roehrig, 2021). Students' self- efficacy is improved in cases that students consider their previous experiences as successful and is reduced when they perceive their experiences as unsuccessful (Capa-Aydin et al., 2018). In chemistry education, it seems that the timing of students' experiences may also affect self-efficacy outcomes (Zhou et al., 2020). Research has also revealed that students' intrinsic motivation is positively related to their academic experience (Liu et al., 2017), and that gender motivational differences can be attributed to the learning experiences (Nissen & Shemwell, 2016). In this respect, there is a need for a deeper understanding of the effect of students' characteristics on their motivation to learn various science-related subjects (Ardura et al., 2021; Pintrich, 2003).

Taking into account previous research findings from the authors (Salta & Koulougliotis, 2020), the present research is a comprehensive examination of potential relations between students' motivation and their gender, academic major, and sense about their academic experience.

In previous research conducted by the authors, the focus was primarily on the adaptation and validation of proper instruments for measuring students' motivation to learn chemistry and physics, through a social cognitive perspective (Salta & Koulougliotis 2015, 2020). In the current research, the aim is to examine the effect of various factors on students' motivational beliefs and to explore the relations between motivational components and the factors that affect them. For this purpose, a study was designed and conducted, in order to address the following research question:

Do Greek undergraduate students' experiences from chemistry and physics courses, gender, and academic major reliably affect their motivation to learn chemistry and physics?

## Research Methodology

### *General Background*

The present research adopts a *cross-sectional* research design in which one observes "*what naturally goes on in the world without directly interfering with it by measuring several variables at a single time point*" (Field, 2013). A cross-sectional research design involves the collection of quantitative or quantifiable data on several variables, which are examined in order to reveal patterns of association. Thus, the cross-sectional design has been placed mainly in the context of the quantitative research strategy. When a cross-sectional design uses questionnaires to collect data, it is referred to as a survey design (Bryman, 2012). Moreover, as the research scope is to explore relations between variables using the correlation statistic, the undertaken research is also referred to as correlational. Finally, taking into account that the basic objective of the present correlational research is to explain the association between variables, it is more specifically referred to as explanatory research (Creswell, 2012).


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The present research examines the extent to which 5 domain specific motivational components may be associated with undergraduate students' gender, academic major, and their perception of academic experiences. Quantitative data were collected and analyzed from undergraduate students who responded to the Chemistry Motivation Questionnaire II (CMQ II), the Physics Motivation Questionnaire II (PMQ II) (Salta & Koulougliotis, 2020), the Experience of Chemistry Courses Inventory (ECCI), and the Experience of Physics Courses Inventory (EPCI). The questionnaires were completed anonymously during a period of two-weeks in April 2015.

*Sample*

The research sample consists of 281 full-time undergraduate students (105 males and 176 females) that have been enrolled in a small-sized regional Technological Education Institute (TEI), located in Western Greece. The program of the study leads to the award of a bachelor's degree after four years of full time attendance. The students of the sample were drawn from three different academic departments which offer Bachelors' degrees in the following academic majors: Environmental Technology (ET), ($N = 95$), Conservation of Cultural Heritage (CCH), ($N = 93$), and Food Technology (FT), ($N = 93$). These specific academic majors were chosen because their curricula are mainly science oriented. The sample size is quite larger than 30 participants suggested for a correlational research study and close to 350 individuals that are suggested for a survey study (Creswell, 2012).

The sample was selected based on the easy accessibility to the students and taking into account the fact that they hold characteristics (such as gender representation, different academic majors) that were sought to study (convenience sampling) (Creswell, 2012). The students were informed about the scope of the study and consented to participate. Their participation was voluntary and did not involve any kind of compensation. The ethics committee of the institution provided approval for the study.

It should be noted that during secondary education, both the science curriculum and the corresponding educational materials are identical for all students, as authorized by the Ministry of Education. The academic experience acquired in tertiary education (TEI) refers to the recent past of a few months (for first year undergraduates) and up to three years (for fourth year undergraduates).

*Instrument and Procedures*

*Motivational variables*: Students' motivation to learn physics and chemistry was measured by CMQ II, and the PMQ II (Salta & Koulougliotis, 2020), that constitute the Greek versions (Salta & Koulougliotis, 2015; 2020) of the discipline-specific original instrument known as SMQ II (Glynn et al., 2011). Each instrument uses a "5-point Likert scale" ranging from 0 (never) to 4 (always) to measure the following five distinct motivational components: self-efficacy (SE), self-determination (SD), intrinsic motivation (IM), career motivation (CM) and grade motivation (GM). The Greek CMQ II and PMQ II have strong psychometric properties and in addition strong evidence has been provided with regard to their validity (Salta & Koulougliotis, 2020). The reliabilities (Cronbach's $\boldsymbol{\alpha}$) of all motivation scales of CMQ II and PMQ II, have values larger than 0.84, indicating a good overall reliability according to DeVellis (2003).

*Academic experience variables:* Students' academic experiences from physics and chemistry courses were determined by the students' reports to the following 4 items: i) the textbooks, ii) the teacher, iii) the laboratory and iv) the course in total. A Likert-type scale ranging from 1 (very negative) to 4 (very positive) was employed. Thus, the questionnaire for each discipline course (physics or chemistry) contained a total of 8 questions (4 referring to high school and 4 referring to TEI experience). Therefore, a total of 16 experience items were made up.

Construct validity of the experience inventories (ECCI and EPCI) was tested using principal components exploratory factor analysis that was independently conducted on each set of 8 items (one for the ECCI, Table 1, and one for the EPCI, Table 2) with varimax rotation, in order to examine the number of factors-constructs existing among the items-variables related to each discipline course (Anastasi & Urbina, 1997; Field, 2013). For both inventories, the Bartlett's test of sphericity has values with a significance level of $p < .001$ thus indicating the appropriateness of the factor models. The Kaiser–Meyer–Olkin (KMO) measure verified the sampling adequacy for the analysis with KMO taking values of .79 and .81 for the ECCI and EPCI, respectively. In addition, the KMO values of all individual items are larger than .73, which is quite higher than the acceptable limit of .50 (Field, 2013).


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**Table 1**
*Results from an Exploratory Factor Analysis of the Experience of Chemistry Courses Inventory (ECCI)*

| ECCI item | Factor loading | |
|---|---|---|
| | Factor 1 | Factor 2 |
| Factor 1. Experience from high school chemistry courses | | |
| How would you characterize your experience … | | |
| … from high school chemistry courses overall? | **.856** | .178 |
| … from the teachers who taught you chemistry at high school? | **.805** | .041 |
| … with high school chemistry textbooks? | **.799** | .175 |
| … from the high school chemistry labs? | **.780** | .099 |
| Factor 2. Experience from TEI chemistry courses | | |
| How would you characterize your experience … | | |
| … from the teachers who taught you chemistry at TEI? | .017 | **.834** |
| … from TEI chemistry courses overall? | .237 | **.827** |
| … from the TEI chemistry labs? | .103 | **.775** |
| … with TEI chemistry textbooks? | .135 | **.729** |
| | | |
| Eigenvalues (Variance) | 3.443 (43.039) | 1.855 (23.186) |
| Cronbach's α | .836 | .813 |

*Note*. Factor loadings over .40 appear in bold

Each analysis resulted in two factors with eigenvalues larger than Kaiser's criterion of 1 (Field, 2013) for each discipline course. These two factors, in combination, explained 66.23% and 68.19% of the variance for the ECCI and the EPCI, respectively. An examination of the two scree-plots confirmed the two-factor solution. The rotated factor loadings for the items of both inventories are presented in Tables 1 and 2. The clustering of the items suggests that factor 1 represents experience from high school courses while factor 2 represents experience from TEI courses. The experiences from TEI physics, high school physics, TEI chemistry and high school chemistry courses all had high reliabilities with Cronbach's α having values larger than 0.81, indicating a good overall reliability according to DeVellis (2003).

**Table 2**
*Results from an Exploratory Factor Analysis of the Experience of Physics Courses Inventory (EPCI)*

| EPCI item | Factor loading | |
|---|---|---|
| | Factor 1 | Factor 2 |
| Factor 1. Experience from high school physics courses | | |
| How would you characterize your experience … | | |
| … from the TEI physics labs? | **.826** | .116 |
| … from TEI physics courses overall? | **.819** | .178 |
| … from the teachers who taught you physics at TEI? | **.792** | .190 |
| … with TEI physics textbooks? | **.791** | .211 |
| Factor 2. Experience from TEI physics courses | | |
| How would you characterize your experience … | | |
| … high school physics courses overall? | .206 | **.835** |
| … from the teachers who taught you physics at high school? | .053 | **.834** |


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| EPCI item | Factor loading | |
|---|---|---|
| | Factor 1 | Factor 2 |
| … with high school physics textbooks? | .256 | **.780** |
| … from the high school physics labs? | .201 | **.756** |
| | | |
| Eigenvalues (Variance) | 3.854 (48.179) | 1.601 (20.006) |
| Cronbach's α | .845 | .838 |

*Note*: Factor loadings over .40 appear in bold

*Data Analysis*

A multiple stepwise regression analysis was conducted to examine the relations between a set of predictors (gender, academic major, and academic experiences) and a criterion (outcome) variable (motivational component) (Tabachnick & Fidell, 2013). Each outcome variable $Y_i$ is predicted by a linear combination of two or more predictor variables ($X_{1i}$, $X_{2i}$, …, $X_{ni}$) according to the model: $Y_i=(b_0 + b_1X_{1i}+ b_2X_{2i} + … + b_nX_{ni})+e_i$. Beta (b) is the regression coefficient of each predictor associated with it, and $b_0$ is equal with the value of each outcome when all predictors have zero values (Field, 2013). The selected predictors were based on the literature review that demonstrates their importance and which was presented in the Introduction section. The stepwise method of multiple regression can only be used for prediction, not explanation (Tabachnick & Fidell, 2013). The predictor variables are entered into the model one by one in an order based on a purely mathematical criterion (e.g., the highest simple correlation with the outcome) (Field, 2013).

The research question was addressed by a linear multiple stepwise regression that was conducted to predict students' motivation to learn chemistry and physics as measured by CMQ II and PMQ II, respectively based on three factors: gender, academic major, academic experience of related courses in either high school or TEI. The predictors gender and academic major are categorical variables with two and three levels respectively, and they were transformed into dichotomous variables via the process of 'dummy coding.' This process creates new binary variables which can distinguish between the presence or absence of each level of these variables (Tabachnick & Fidell, 2013). For example, academic major as a categorical variable, has been coded on three different levels: 1 = ET, 2 = CCH, and 3 = FT. To use this categorical variable into the multiple regression, it was recoded into two new dichotomous variables which are called dummy variables (ET = 1 vs. the other two majors = 0, and CCH = 1 vs. the other two majors = 0). Students of the FT major is encoded by a "0" in both dichotomous variables thus removing the necessity for a third new variable. The gender variable was similarly recoded as "female".

Initial examination of descriptive statistics regarding both the independent and dependent variables provided a useful summary. Subsequently, a correlation analysis was conducted resulting to a correlation matrix involving all pairwise Pearson coefficients, the corresponding significance values, and the number of cases contributing to each correlation. The correlation matrix provides an idea of the relations between predictors and the outcome variables. Stepwise multiple regression was employed. Data were analyzed using SPSS Statistics 26.0.

## Research Results

A stepwise multiple regression analysis was independently conducted on each of the 10 motivational components (five for the chemistry and five for the physics) as dependent variables and gender ("female"), academic major (ET, CCH) and students' experiences from high school (HS) and TEI chemistry (ChemHS, ChemTEI) and physics (PhysHS, PhysTEI) courses as independent variables.

A crucial consideration for models with more than one predictor is multicollinearity between predictors that makes difficult to assess the individual importance of each predictor. Tables 3 and 4 present the correlation coefficients Pearson's r between the scores of the predictors (independent variables) and the outcomes (dependent variables). These correlation matrices provide a rough idea about the relations between the outcome and predictor variables. As seen in Tables 3 and 4, from all predictors, students' experiences from TEI chemistry and physics courses


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(Experience-ChemTEI and Experience-PhysTEI) show the highest correlations (.320 ≤ *r* ≤ .615 and .284 ≤ *r* ≤ .476, respectively) with the outcome variables (motivational components), and thus it is likely that these variables are the best predictors of students' motivational components.

**Table 3**
*Pearson's Correlation Coefficients (r) between Every Pair of Variables in Chemistry Related Motivational Components*

| Dependent Variables | | Independent Variables | | | | |
|---|---|---|---|---|---|---|
| | | Female | ET | CCH | Experiences-ChemHS | Experiences-ChemTEI |
| IM | *r* | .082 | .138* | -.342** | .379** | .615** |
| | *N* | 275 | 275 | 275 | 275 | 275 |
| SD | *r* | .124* | -.066 | -.124* | .148** | .320** |
| | *N* | 274 | 274 | 274 | 274 | 274 |
| SE | *r* | .026 | .161** | -.392** | .486** | .604** |
| | *N* | 274 | 274 | 274 | 274 | 274 |
| CM | *r* | .084 | -.123* | -.194** | .304** | .413** |
| | *N* | 274 | 274 | 274 | 274 | 274 |
| GM | *r* | .018 | .118* | -.342** | .408** | .490** |
| | *N* | 274 | 274 | 274 | 274 | 274 |

*$p < .05$. **$p < .01$.

**Table 4**
*Pearson's Correlation Coefficients (r) between Every Pair of Variables in Physics Related Motivational Components*

| Dependent Variables | | Independent Variables | | | | |
|---|---|---|---|---|---|---|
| | | Female | ET | CCH | Experience-PhysHS | Experience-PhysTEI |
| IM | *r* | -.122* | .284** | -.338** | .366** | .438** |
| | *N* | 276 | 276 | 276 | 276 | 276 |
| SD | *r* | .041 | .051 | -.218** | .140** | .290** |
| | *N* | 276 | 276 | 276 | 276 | 276 |
| SE | *r* | -.148** | .183** | -.403** | .373** | .476** |
| | *N* | 276 | 276 | 276 | 276 | 276 |
| CM | *r* | -.088 | .197** | -.159** | .184** | .284** |
| | *N* | 276 | 276 | 276 | 276 | 276 |
| GM | *r* | -.091 | .216** | -.361** | .296** | .423** |
| | *N* | 276 | 276 | 276 | 276 | 276 |

*$p < .05$. **$p < .01$.

Using the stepwise method of multiple regression, significant models emerge (Tables 5 and 6). Tables 5 and 6 contain information about the fit of different regression models in predicting students' motivation to learn chemistry and physics, respectively. Each set of summary statistics is reported for each motivational component: IM, SD, SE, CM, and GM.

The assumption of independent errors is tested by the Durbin–Watson test statistic, which tests for serial cor-


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relations between errors (Field, 2013). All values of Durbin–Watson statistic range between 1.658 and 2.000 (Tables 5 and 6); therefore, there is no cause for concern arising from values less than 1 or greater than 3 (Field, 2013).

**Table 5**
*Regression Models Summary and ANOVA for Chemistry- Related Motivational Components*

| Dependent Variables | Model Summary | | | | ANOVA | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|
| | Model | *R* | $R^2$ | Adjusted $R^2$ | *F* | *df* | *p* | |
| IM | 1 | .615 | .379 | .376 | 166.375 | (1, 273) | < .001 | |
| | 2 | .648 | .420 | .416 | 98.540 | (2, 272) | < .001 | |
| | 3 | .657 | .431 | .425 | 68.476 | (3, 271) | < .001 | |
| | 4 | .663 | .439 | .431 | 52.911 | (4, 270) | < .001 | 1.874 |
| SD | 1 | .320 | .102 | .099 | 31.029 | (1, 272) | < .001 | |
| | 2 | .346 | .119 | .113 | 18.378 | (2, 271) | < .001 | 1.736 |
| SE | 1 | .604 | .365 | .363 | 156.596 | (1, 272) | < .001 | |
| | 2 | .678 | .459 | .455 | 114.990 | (2, 271) | < .001 | |
| | 3 | .698 | .487 | .482 | 85.549 | (3, 270) | < .001 | 1.741 |
| CM | 1 | .413 | .171 | .168 | 55.954 | (1, 272) | < .001 | |
| | 2 | .459 | .210 | .204 | 36.084 | (2, 271) | < .001 | |
| | 3 | .498 | .248 | .240 | 29.677 | (3, 270) | < .001 | |
| | 4 | .522 | .272 | .261 | 25.150 | (4, 269) | < .001 | 1.901 |
| GM | 1 | .490 | .240 | .237 | 85.941 | (1, 272) | < .001 | |
| | 2 | .556 | .309 | .304 | 60.585 | (2, 271) | < .001 | |
| | 3 | .579 | .335 | .328 | 45.425 | (3, 270) | < .001 | 1.734 |

Dependent Variable: IM
Model 1. Predictors: (Constant), Experience-ChemTEI
**Model 2. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS**
Model 3. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS, CCH
Model 4. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS, CCH, Female
Dependent Variable: SD
**Model 1. Predictors: (Constant), Experience-ChemTEI**
Model 2. Predictors: (Constant), Experience-ChemTEI, Female
Dependent Variable: SE
Model 1. Predictors: (Constant), Experience-ChemTEI
**Model 2. Predictors: (Constant), Experiences-ChemTEI, Experiences-ChemHS**
Model 3. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS, CCH
Dependent Variable: CM
Model 1. Predictors: (Constant), Experience-ChemTEI
Model 2. Predictors: (Constant), Experience-ChemTEI, ET
**Model 3. Predictors: (Constant), Experience-ChemTEI, ET, Experience-ChemHS**
Model 4. Predictors: (Constant), Experience-ChemTEI, ET, Experience-ChemHS, CCH
Dependent Variable: GM
Model 1. Predictors: (Constant), Experience-ChemTEI
**Model 2. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS**
Model 3. Predictors: (Constant), Experience-ChemTEI, Experience-ChemHS, CCH

$R^2$ is used to test the overall significance of a model as its value indicates the variance in the outcome which is accounted for by the model. Regarding to Chemistry-IM, the $R^2$ value for the first model is .376, which means that the students experience from chemistry courses in TEI (Experience-ChemTEI) accounts for 37.6% of the variation in the students' intrinsic motivation to learn chemistry. Moreover, when the other three predictors are sequentially included (models 2, 3 and 4) this value increases to 42.0%, 43.1%, and 43.9%, respectively. The inclusion of the three


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additional predictors explains a larger portion of the variation relative to model 1, but only the students' experience from chemistry courses in high school (Experience-ChemHS) contributes an amount which is large enough to support the necessity for model 2. The *F*-statistic and its associated significance value (166.375, $p < .001$ for model 1 and 98.540, $p < .001$ for model 2) indicates that both models overall predict the outcome variable significantly. For models 3 and 4, the values of *F* are still highly significant but quite lower. It is thus deduced that the additional predictors (CCH and Female) in models 3 and 4 do not provide major improvement in the fit. Based on the above overall reasoning Model 2 better fits the data.

The results regarding the components Chemistry-SE and Chemistry-GM show a similar trend with those for Chemistry-IM. Therefore, the choice of two predictors (i.e., model 2) is the one best justified. For the components, Chemistry-SD and the Chemistry-CM, the examination of $R^2$ values and the *F*-statistic (Table 5) leads to the decision that Model 1 and Model 3 better fit the data, respectively.

For the motivational components to learn physics, the examination of the $R^2$ values and *F*-statistic (Table 6), provides evidence that Model 1 for Physics-SD and Physics-CM, and Model 3 for Physics-IM, Physics-SE, and Physics-GM better fit the data.

**Table 6**

*Regression Models Summary and ANOVA for Physics- Related Motivational Components*

| Dependent Variables | Model Summary | | | | ANOVA | | | Durbin-Watson |
|---|---|---|---|---|---|---|---|---|
| | Model | *R* | $R^2$ | Adjusted $R^2$ | *F* | *df* | *p* | |
| IM | 1 | .438 | .192 | .189 | 65.128 | (1, 274) | < .001 | |
| | 2 | .483 | .233 | .228 | 41.567 | (2, 273) | < .001 | |
| | 3 | .513 | .263 | .255 | 32.412 | (3, 272) | < .001 | 1.980 |
| SD | 1 | .290 | .084 | .081 | 25.214 | (1, 274) | < .001 | 1.658 |
| SE | 1 | .476 | .226 | .223 | 80.088 | (1, 274) | < .001 | |
| | 2 | .522 | .272 | .267 | 51.099 | (2, 273) | < .001 | |
| | 3 | .555 | .309 | .301 | 40.456 | (3, 272) | < .001 | 1.973 |
| CM | 1 | .284 | .081 | .077 | 24.032 | (1, 274) | < .001 | |
| | 2 | .314 | .099 | .092 | 14.953 | (2, 273) | < .001 | 1.962 |
| GM | 1 | .423 | .179 | .176 | 59.626 | (1, 274) | < .001 | |
| | 2 | .465 | .217 | .211 | 37.720 | (2, 273) | < .001 | |
| | 3 | .483 | .233 | .225 | 27.605 | (3, 272) | < .001 | 2.000 |

Dependent Variable: IM
Model 1. Predictors: (Constant), Experience-PhysTEI
Model 2. Predictors: (Constant), Experience-PhysTEI, Experience-PhysHS
**Model 3. Predictors: (Constant), Experience-Phys**TEI**, Experience-PhysHS, ET**
Dependent Variable: SD
**Model 1. Predictors: (Constant), Experience-Phys**TEI
Dependent Variable: SE
Model 1. Predictors: (Constant), Experience-PhysTEI
Model 2. Predictors: (Constant), Experience-PhysTEI, CCH
**Model 3. Predictors: (Constant), Experience-Phys**TEI**, CCH, Experience-PhysHS**
Dependent Variable: CM
**Model 1. Predictors: (Constant), Experience-Phys**TEI
Model 2. Predictors: (Constant), Experience-PhysTEI, ET
Dependent Variable: GM
Model 1. Predictors: (Constant), Experience-PhysTEI
Model 2. Predictors: (Constant), Experience-PhysTEI, CCH
**Model 3. Predictors: (Constant), Experience-Phys**TEI**, CCH, Experience-PhysHS**


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The adjusted $R^2$ value provides rough evidence of how well the model generalizes. In all cases the adjusted $R^2$ values are very close to the values of $R^2$ with the differences "$R^2$- adjusted $R^2$" in the final models ranging between .003 to .008 (Tables 5 and 6). These small shrinkages indicate high predictive power of the derived models.

Two indicators for identifying multicollinearity are the *variance inflation factor* (VIF) and its reciprocal (1/VIF) known as the *tolerance* statistic (Field, 2013). Values of VIF which are above 10 (or corresponding tolerance values which are below 0.1) indicate a serious problem. A potential problem is indicated if VIF is above 5, or when tolerance is below 0.2 (Tabachnick & Fidell, 2013). The VIF values and tolerance statistics for all models (Tables 7 and 8) do not fall close to these ranges and therefore, it can be safely concluded that there is no collinearity within the data.

**Table 7**

*Regression Models Coefficients and Collinearity Statistics for Chemistry-Related Motivational Components*

| Dependent Variables | | | Models Coefficients | | | | | Collinearity statistics | |
|---|---|---|---|---|---|---|---|---|---|
| | | Model | *b* | *b** | *SE* | *t* | *p* | Tolerance | VIF |
| IM | 2 | (Constant) | -2.407 | 0.964 | | -2.497 | .013 | | |
| | | Experience-ChemTEI | 0.896 | 0.079 | 0.551 | 11.391 | < .001 | 0.910 | 1.099 |
| | | Experience-ChemHS | 0.300 | 0.068 | 0.213 | 4.411 | < .001 | 0.910 | 1.099 |
| SD | 1 | (Constant) | 4.452 | 1.056 | | 4.216 | < .001 | | |
| | | Experience-ChemTEI | 0.497 | 0.089 | 0.320 | 5.570 | < .001 | 1.000 | 1.000 |
| SE | 2 | (Constant) | -4.790 | 0.981 | | -4.883 | < .001 | | |
| | | Experience-ChemTEI | 0.861 | 0.082 | 0.499 | 10.557 | < .001 | 0.894 | 1.119 |
| | | Experience-ChemHS | 0.479 | 0.070 | 0.324 | 6.851 | < .001 | 0.894 | 1.119 |
| CM | 3 | (Constant) | 1.292 | 1.172 | | 1.102 | .271 | | |
| | | Experience-ChemTEI | 0.670 | 0.098 | 0.384 | 6.809 | < .001 | 0.875 | 1.143 |
| | | ET | -2.197 | 0.546 | -0.216 | -4.024 | < .001 | 0.964 | 1.037 |
| | | Experience-ChemHS | 0.308 | 0.084 | 0.206 | 3.678 | < .001 | 0.889 | 1.124 |
| GM | 2 | (Constant) | -1.481 | 1.212 | | -1.222 | .223 | | |
| | | Experience-ChemTEI | 0.753 | 0.101 | 0.400 | 7.479 | < .001 | 0.894 | 1.119 |
| | | Experience-ChemHS | 0.449 | 0.086 | 0.278 | 5.197 | < .001 | 0.894 | 1.119 |

*Note*: *b*: Unstandardized coefficients, *b**: Standardized coefficients,

In multiple regression, estimates of the b values show the specific contribution of each predictor to the model, after assuming a constant effect for all other predictors. Based on the above-described analysis and the unstandardized coefficients b which are statistically significant ($p < .05$) (Tables 7 and 8), the following ten model equations (one for each motivational component) were extracted.

Chemistry-IM = -2.407 + 0.896 (Experience-ChemTEI) + 0.300 (Experience-ChemHS)
Chemistry-SD = 4.452 + 0.497 (Experience-ChemTEI)
Chemistry-SE = -4.790 + 0.861 (Experience-ChemTEI) + 0.479 (Experiences-ChemHS)
Chemistry-CM = 0.670 (Experience-ChemTEI) - 2,197 (ET) + 0.308 (Experience-ChemHS)
Chemistry-GM = 0.753 (Experience-ChemTEI) + 0.449 (Experience-ChemHS)
Physics-IM = 0.475 (Experience-PhysTEI) + 0.305 (Experience-PhysHS) + 1.723 (ET)
Physics-SD = 4.928 + 0.428 (Experience-PhysTEI)
Physics-SE =0.429 (Experience-PhysTEI) - 2.246 (CCH) + 0.297 (Experience-PhysHS)
Physics-CM = 4.712 + 0.437 (Experience-PhysTEI)
Physics-GM = 4.204 + 0.450 (Experience-PhysTEI) - 2.264 (CCH) + 0.226 (Experience-PhysHS)


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**Table 8**

*Regression Models Coefficients and Collinearity Statistics for Physics-Related Motivational Components*

| Dependent Variables | | | Models Coefficients | | | | | Collinearity statistics | |
|---|---|---|---|---|---|---|---|---|---|
| | | Model | *b* | *b** | *SE* | *t* | *p* | Tolerance | VIF |
| IM | 3 | (Constant) | 1.654 | 0.935 | | 1.770 | .078 | | |
| | | Experience-PhysTEI | 0.475 | 0.089 | 0.310 | 5.326 | < .001 | 0.800 | 1.249 |
| | | Experience-PhysHS | 0.305 | 0.083 | 0.210 | 3.668 | < .001 | 0.825 | 1.212 |
| | | ET | 1.723 | 0.518 | 0.178 | 3.323 | .001 | 0.941 | 1.063 |
| SD | 1 | (Constant) | 4.928 | 0.913 | | 5.396 | < .001 | | |
| | | Experience-PhysTEI | 0.428 | 0.085 | 0.290 | 5.021 | < .001 | 1.000 | 1.000 |
| SE | 3 | (Constant) | 1.965 | 1.054 | | 1.865 | .063 | | |
| | | Experience-PhysTEI | 0.429 | 0.091 | 0.285 | 4.717 | < .001 | 0.695 | 1.439 |
| | | CCH | -2.246 | 0.536 | -0.235 | -4.189 | < .001 | 0.805 | 1.243 |
| | | Experience-PhysHS | 0.297 | 0.079 | 0.209 | 3.771 | < .001 | 0.829 | 1.206 |
| CM | 1 | (Constant) | 4.712 | 0.954 | | 4.937 | < .001 | | |
| | | Experience-PhysTEI | 0.437 | 0.089 | 0.284 | 4.902 | < .001 | 1.000 | 1.000 |
| GM | 3 | (Constant) | 4.204 | 1.232 | | 3.413 | .001 | | |
| | | Experience-PhysTEI | 0.450 | 0.106 | 0.269 | 4.229 | < .001 | 0.695 | 1.439 |
| | | CCH | -2.264 | 0.627 | -0.214 | -3.614 | < .001 | 0.805 | 1.243 |
| | | Experience-PhysHS | 0.226 | 0.092 | 0.143 | 2.449 | .015 | 0.829 | 1.206 |

*Note*. *b*: Unstandardized coefficients, *b**: Standardized coefficients

## Discussion

The present research examines factors that affect the motivation for chemistry and physics learning among undergraduate students via multiple regression analysis. As noted in the Introduction section, there is a need for a deeper understanding of the effect of students' related variables on their motivation to learn various specific science subjects (e.g., Ardura et al., 2021; Pintrich, 2003). The present research provides strong evidence that undergraduate students' perceptions of their experiences from chemistry and physics courses affect their motivational beliefs related with chemistry and physics learning.

With regard to motivation for chemistry learning, based on the sizes of the correlation coefficients *r* (Cohen, 1992) reported in Tables 3 and 4, our research shows that students' experience from chemistry courses in TEI has a large effect on their intrinsic motivation, self-efficacy and grade motivation and a medium effect on self-determination and career motivation. On the other hand, students' experience from chemistry courses in high school has a large effect on their self-efficacy, a medium effect on their intrinsic motivation, career motivation, and grade motivation, and a small effect on their self-determination.

With regard to motivation for physics learning, the corresponding values of *r*, show that students' experience from physics courses in TEI has a large effect on their intrinsic motivation self-efficacy and grade motivation and a medium effect on self-determination and career motivation. With regard to students' experience from


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physics courses in high school, there is a medium effect on their intrinsic motivation, self-efficacy and grade motivation and a small effect on both self-determination and career motivation.

Previous research has provided evidence that mastery experience is the most salient predictor of the development of self-efficacy (e.g., Britner & Pajares, 2006; Chen & Usher, 2013; Kıran & Sungur, 2012), and the timing of mastery experiences also affects self-efficacy beliefs (Zhou et al., 2020). The importance of mastery experience in shaping self-efficacy is consistent with the results of the current research: the values of the correlation coefficients Pearson's *r* regarding self-efficacy are overall the highest observed in comparison with those of the other four motivational components for both chemistry and physics learning and for both recent (from TEI courses) and less recent experiences (from high school courses).

Examining the effect of gender, the sizes of the *r* values denote very few statistically significant effects. Thus, a small effect on self-determination towards chemistry learning was found ($r = .124$) and with regard to physics learning a small effect on intrinsic motivation ($r = -.122$) and self-efficacy ($r = -.148$) were noted. The positive sign means that female students have higher motivation relative to their male peers while the opposite applies for the negative sign. The trend which regards self-determination is in accordance with the one observed in past research which probed undergraduate students' motivation to learn science (Glynn et al., 2009, 2011). Regarding intrinsic motivation, past research which aimed at measuring the motivation to learn science of either undergraduate (Glynn et al., 2009) or secondary school students (Bryan et al., 2011), has provided similar results. The small gender effect is consistent with the notion that this variable most probably does not have a direct connection with motivation to learn science and it rather acts indirectly via personal characteristics, such as the students' cognitive style (Zeyer, 2018), which are not dependent on gender.

Turning to the effect of the academic major, the results indicate that the CCH major correlates negatively with all motivational components for both disciplines, i.e., that these students depict lower motivation relative to the ones of the other two majors. Based on the values of the correlation coefficients *r*, the effect is medium with regard to intrinsic motivation, self-efficacy, and grade motivation, and small with regard to self-determination and career motivation for chemistry and physics learning, respectively. The ET major relates positively with a small effect for intrinsic motivation, self-efficacy, and grade motivation for chemistry and physics learning, respectively. With regard to career motivation the effect of the ET major is different for the two disciplines with a small negative effect for chemistry and a small positive effect for physics. The lower motivation of the CCH majors may be related to the dual nature of this subject of study, which is both artistic and scientific, a fact which does not apply in the other two majors (ET and FT) which do not possess the artistic facet. As mentioned in the Introduction, the differential motivation to learn science between science and non-science majors has been documented in previous research (Glynn et al., 2011). This research advances the field further in two ways: on one hand by examining the motivation to learn specific science subjects (chemistry, physics) and on the other by comparing three academic majors which are all science related.

Ten models emerged via the stepwise method of multiple regression, one for each motivational component related to chemistry and physics learning. The absence of gender from all ten equations is consistent with the fact that the gender effect on motivation to learn chemistry and physics is small and has much less predictive power relative to the other factors examined in this research.

The role of the academic major on motivation for chemistry and physics learning is brought out via the appearance of this independent variable in the regression equations describing the following three motivational components: Chemistry-CM and Physics-SE and GM.

However, the independent variables with the highest predicting power are those related with students' academic experiences from the attendance of chemistry and physics related courses either in TEI or in high school. More specifically, the student experience from TEI courses is the only independent variable which appears in all respective equations and the one contributing more to the variation explained by each model (Tables 5 and 6). In fact, three of the ten models (Dependent variables: Chemistry-SD, SD, and CM) contain experience from TEI courses as the sole predicting variable. The second most prominent predicting variable is the experience from the attendance of the high school courses which appears in the models of seven motivational components (Chemistry-IM, SE, CM, and GM; Physics-IM, SE, and GM). As seen in Tables 7 and 8, the values of the coefficients *b*, in all of these seven models, are always considerably larger for the experience from TEI relative


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to the one from high school (by factors ranging between 1.68 – 2.99 for chemistry and between 1.44 – 1.99 for physics). In addition, an examination of the values of the Pearson's *r* coefficients (Tables 3 and 4) shows that, for both chemistry and physics motivations, all values concerning experience from TEI are larger from those concerning experience from high school. It is thus deduced that the more recent experiences seem to exert a significantly more intense effect in shaping students' motivation to learn chemistry and physics relative to the ones from the more distant past.

Finally, reference should be made to some limitations of the present research. The fact that the results deduced are based exclusively on self-report data is considered the main limitation. In addition, the research relies on a cluster sampling method and the students originate from only one academic institution. Taking into account, that the student population of all three departments originates from all over the country and possesses a mosaic of demographic characteristics as is the case in all Greek public tertiary education institutions, the possibility of erroneous inferences is probably small.

## Conclusions and Implications

In this research, the possible effect of three factors in shaping Greek undergraduate students' motivation to learn chemistry and physics has been explored. Five different motivational components were measured for both chemistry and physics; namely intrinsic motivation (IM), self-determination (SD), self-efficacy (SE), career motivation (CM) and grade motivation (GM). The factors examined were students' gender, academic major, and experience from the attendance of physics and chemistry related courses. Two subfactors, one related with the experience from the courses in the tertiary education institution and one with the one from the courses in high school, constituted the factor referring to the experience. Statistical analysis via stepwise multiple regression provided strong evidence for the following:

Male and female undergraduate students showed overall similar motivations for chemistry and physics learning. Out of the ten measured motivational components, statistically significant differences of small size were identified for only three components: Chemistry-SD with females exceeding males and Physics –IM and SE with the opposite trend.

Undergraduate students of different science-related academic majors exhibit different motivations for chemistry and physics learning with an effect which has mostly a small size.

Students' experience from the attendance of physics and chemistry related courses both in tertiary as well as in secondary education seems to be the most influential factor (in comparison with the other two) with regard to their motivation to learn physics and chemistry. In addition, strong evidence was provided for the significantly larger effect of the more recent experiences relative to the ones from the more distant past.

With regard to the implications for future research, it is first noted that students' experience, as measured in this research and documented via exploratory factor analysis, is a multidimensional factor which involves the role of the teacher, the textbooks employed, the lab work and the overall impression. Thus, the present research points to the fact that a combination of educational interventions should be employed in order to enhance undergraduate students' motivation to engage more intensely in chemistry and physics learning during their studies. The documented more important role of the most recent academic experiences supports the notion that motivation to learn science is a malleable construct which is time-dependent and susceptible to changes which, if positive, they can contribute to the promotion of science education.

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## Declaration of Interest

The authors declare no competing interest.


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