Scientific paper

Pre-service primary school teachers' motivation for learning chemistry and their gifted behavioural scores in chemistry

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Abstract

Motivation is an important factor predicting students' academic achievements, and higher levels of motivation have been observed in gifted students. Building on this, the present study explores the relationship between pre-service primary school teachers' motivation for learning chemistry, their intrinsic motivation for understanding the chemistry triplet, and their gifted behavioural scores in chemistry. A total of 80 first-year pre-service teachers participated in the study using three questionnaires. Results showed no statistically significant differences between students' overall motivation for learning chemistry (Relative Autonomous Index - RAI) and their intrinsic motivation for learning the chemistry triplet, nor between motivation and gifted behavioural scores. However, significant differences were found between students gifted behavioural scores and their intrinsic motivation across all three levels of chemical representation, with gifted students showing higher motivation. Students demonstrated the highest intrinsic motivation for learning on the macroscopic level, while they were least motivated to learn the symbolic level. These findings highlight the importance of tailored instructional strategies that support both gifted and non-gifted students in navigating the abstract nature of chemical concepts. Enhancing visualization and fostering autonomy may improve intrinsic motivation and conceptual understanding. The study also suggests that gifted behavioural scores play a role in students' engagement with complex scientific content, emphasizing the need to consider individual learner characteristics in teacher education programs.

Keywords: motivation for learning chemistry, intrinsic motivation for learning chemistry triplet, giftedness in chemistry, chemistry triplet.

1. Introduction

When learning chemistry, students encounter various visualizations that represent chemical phenomena and processes, unobservable with the naked eye.[1] To adequately understand certain phenomena, students must navigate through different levels of presentation.[2] It is crucial to integrate all three levels in teaching chemistry so that students can construct a scientifically accurate mental model of the chemical phenomena.[3] Visualization elements play an important role in chemistry learning[4] by presenting an analogical model of chemical phenomena.[5] These interactive visualization elements can be two-dimensional or three-dimensional images, especially for more complex and abstract phenomena.[6] Previous studies have shown that students using 3D dynamic presentations develop a better understanding of chemical phenomena.[7] Therefore, chemistry education should incorporate diverse visual elements to facilitate learning and prevent misconceptions.[1] However, earlier research revealed that primary school teachers hold misconceptions about the triple nature of chemical phenomena,[8,9] indicating that strategies to enhance laboratory work should be integrated into primary school teacher education.[10]

One of the important predictors of students' academic achievements is motivation, particularly intrinsic motivation.[11] Motivation has been recognized as a significant factor influencing students' engagement in general chemistry.[12] Some previous studies[13] have reported only weak correlations between students' intrinsic motivation and their chemistry knowledge achievements. Furthermore, intrinsic motivation tends to decrease as the level of abstraction increases, especially when learners are introduced to symbolic and submicroscopic representations in chemistry. As a result, intrinsic motivation appears to be particularly malleable in chemistry courses where abstract

concepts are emphasized.[14] Another important factor, influencing students' learning achievement is giftedness. Gifted students tend to show greater interest in learning chemistry[15,16] and their motivation plays a crucial role in achieving academic success.[15] Additionally, gifted students typically acquire abstract concepts more quickly and with less instructional support, which results in fewer learning difficulties in chemistry courses.[16] Results in previous studies vary, and little is known about how intrinsic motivation differs across macro, submicroscopic, and symbolic levels. Moreover, the interaction between motivation and students' giftedness has received limited attention. Understanding these relationships is essential for designing chemistry instruction that supports both conceptual learning and engagement.

2. Theoretical background

2.1. *Motivation and intrinsic motivation*

Motivation is a key factor in learning chemistry; it is a cognitive process that facilitates learning[17] and it is the primary reason individuals remain engaged in certain behaviours.[18] Motivation can be intrinsic—arising from within the individual or extrinsic, driven by external factors.[19] Intrinsic motivation consists of three interconnected components: (1) challenge, (2) interest and (3) importance value.[18] According to self-determination theory (SDT), motivation increases when students experience autonomy, competence and relatedness. In chemistry education, this theory explains how students' perceived competence may decline when faced with abstract and complex content.[20] Thus, preserving students' motivation across the macroscopic, submicroscopic and symbolic levels of chemical presentations is essential for achieving better learning outcomes.[21]

SDT[20] is a well-established theory of human motivation that has been applied across various settings and studies. In general, motivation is a construct that enables individuals to store information in their long-term memory.[17] It is the primary reason the learning process begins and why individuals maintain certain behaviours.[18] Motivation can be divided into two types: (1) intrinsic motivation, which originates from within the individual, and (2) extrinsic motivation, which arises from external factors.[19] Intrinsic motivation is a prototype of autonomous activity; when people are intrinsically motivated, they exhibit greater self-determination (autonomy). In contrast, extrinsically motivated activities tend to be more controlled.[20]

Furthermore, SDT established different types of motivation along a self-determination continuum (Figure 1) ranging from more autonomous (self-determined, internal) to less autonomous (less self-determined, more external) forms.[22] Within this framework, three broad categories of motivation are identified: (1) intrinsic motivation, (2) extrinsic motivation, and (3) amotivation. Amotivation reflects an individual's lack of intention to act; amotivated individuals engage in activities without intent, merely going through the motions without valuing the activity.[23] Extrinsic motivation is further subdivided into (1) external regulations, (2) introjected regulations, (3) identified regulations, and (4) integrated regulations.[20] Within Self-Determination Theory developed by Richard M. Ryan and Edward L. Deci, the Relative Autonomous Index (RAI) represents a composite indicator of the degree to which an individual's motivation is self-determined. The RAI is calculated as the difference between autonomous and controlled forms of regulation, with higher values indicating more autonomous (internally regulated) motivation and lower values reflecting more controlled motivation. This index thus provides a single continuous measure of students' relative motivational orientation along the autonomy–control continuum.[24]

A previous study[25] reported that students with higher motivation for learning chemistry tend to be more mo-

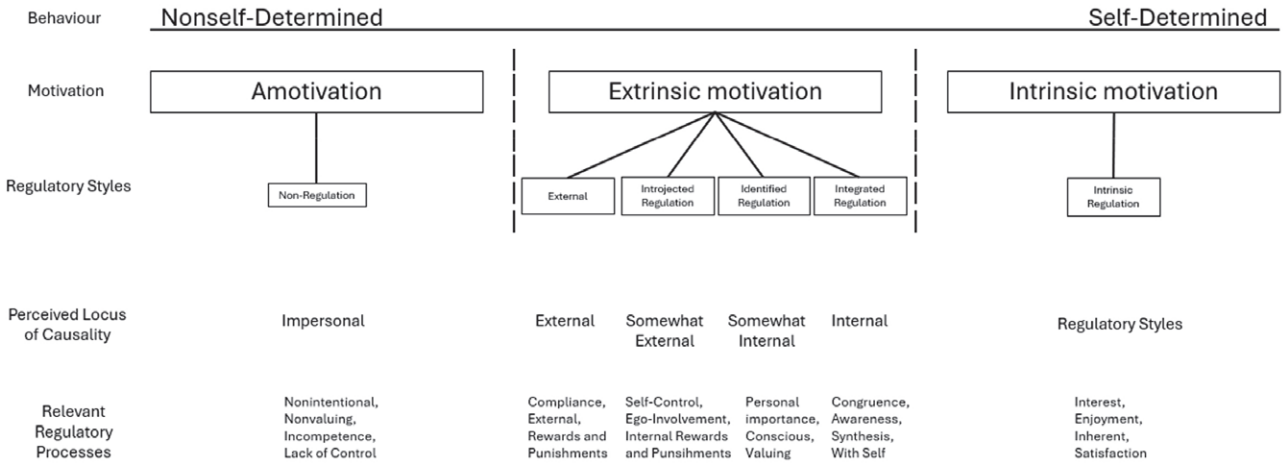


Figure 1. The Self-Determination continuum showing types of motivation with their regulatory styles, locus of causality.[20]

tivated to learn the symbolic level of chemistry concepts. This may be because students' perceived competence decreases when they encounter abstract and complex content.[20] Other studies[26] indicate that students are generally least motivated to learn concepts at the symbolic level. Additionally, several studies[27–30] have examined the correlation between students' motivation and their learning achievements, identifying motivation as a predictor of academic achievement. Similar findings were reported by Juriševič et al.[26] however, the correlation between students' motivation levels and their performance was not strong. Given the importance of motivation in relation to students' performance in chemistry, further thorough investigations are needed to better understand the relationship between students' motivation for learning different presentations of chemical concepts.

2.2. Giftedness

Another important factor influencing students' motivation is giftedness.[31,32] Students who perform significantly better than their peers are referred to as gifted students.[33] They possess learning abilities significantly above average, and demonstrate outstanding achievements in specific academic areas, the arts, or sports.[17] It is important to apply appropriate instructional strategies when working with gifted students,[34] as they require learning environments that support intrinsic motivation and promote autonomy through intellectually challenging tasks.[32] To enhance gifted students' motivation for learning, they must be given tasks that are sufficiently challenging.[35,36] Gifted students require learning environments that nurture intrinsic motivation and foster autonomy through intellectually challenging tasks.[32] Topics such as the triple nature of chemical phenomena, taught with specific educational strategies,[5,37] tend to be more comprehensible and engaging for gifted students,[3] as these concepts present a greater cognitive challenge.[32] For many years, IQ tests have been the classical method for identifying gifted students. However, Sumida and Ohashi[32] emphasize that general behavioural characteristics can also be informative and propose a checklist for identifying gifted behaviour in science. They note that traits such as strong memorization skills or the ability to focus for extended periods are not necessarily indicative of giftedness. It is also suggested that students' self-reported views on the role of chemistry in their everyday lives may be used to extrapolate their giftedness in chemistry.[33]

Previous studies[27,38] have shown that both intrinsic and extrinsic types of motivation are present in gifted students. Moreover, both types of motivation can predict gifted students' academic achievement.[27] Agaliotis and Kalyva[39] reported higher levels of intrinsic motivation among gifted students. However, after primary school, levels of extrinsic motivation and amotivation tend to decline among gifted students, which may reduce differences between them and their peers.[40] Other studies[30,36,41] have found differences in motivation levels between gifted and non-gifted students. For example, Paz-Baruch and Hazema[41] reported statistically significant differences in motivation levels. A systematic review by Slapničar et al.[42] found that gifted students learn more effectively using models than non-gifted students. Interestingly, gifted students also tend to rely more on the symbolic level when learning chemistry.

Overall, there is a lack of research specifically addressing the intrinsic motivation of gifted versus non-gifted students for learning at different representational levels in chemistry. Furthermore, comparative studies investigating the motivational differences between these two groups in the context of chemistry learning are still scarce.

2.3. Research purpose

The literature suggests that chemistry presents significant challenges for many students, as they often struggle to understand fundamental concepts.[2,26] Pre-service primary school teachers, in particular, have been shown to hold misconceptions about the triple nature of chemical phenomena,[8] and often lack motivation for learning chemistry.[43] Additionally, among pre-service primary school teachers, a motivation to learn chemical concepts is generally low, but it is suggested that altruistic and intrinsic motives are the primary reasons for choosing the teaching profession,[44] where motivation for learning chemical concepts needed to adequately teach primary school science is not relevant. It is therefore essential to support both general and specific types of student motivation – intrinsic and extrinsic – as these factors have been identified as predictors of students' academic achievement.[23,24,45] It is important that pre-service primary school teachers demonstrate a high level of scientific aptitude, as this enables them to design and implement creative, pedagogically sound science instruction. Such competence is essential for supporting primary school students in developing scientifically accurate conceptual understanding and for minimizing the formation of misconceptions. A review of the existing literature indicates that there is a lack of empirical research examining the relationship between students' motivation and giftedness in chemistry. In particular, no relevant studies have addressed the potential crossover or interaction between these two constructs. From this perspective, the present study aims to address this gap by providing empirical insight into the interplay between motivation and giftedness in chemistry education.

Accordingly, this study aims to investigate whether there are correlations between students' RAI for learning chemistry, their intrinsic motivation for learning the chemistry triplet and their gifted behavioural scores in chemistry.

To address the existing gaps in this area of research, the following three research questions were formulated:

(1) Are there statistically significant differences in motivation for learning chemistry (RAI) among students with varying levels of intrinsic motivation for learning chemistry at the macroscopic, submicroscopic, and symbolic levels?
(2) Are there statistically significant differences in motivation for learning chemistry (RAI) among students with different levels of gifted behavioural scores?
(3) Are there statistically significant differences in gifted behavioural scores among students with different levels of intrinsic motivation for learning chemistry at the macroscopic, submicroscopic, and symbolic levels?

3. Method

A quantitative research approach using the causal non-experimental method of pedagogical research was used in this research.

3.1. Participants

A total of 80 pre-service primary school teachers attending first-year university education in 2025 participated in the study. Their average age was 19 years. All had completed at least five years of chemistry education in lower and upper secondary school, covering all basic chemical concepts (e.g. pure substances and mixtures, atom structure, chemical bonds, chemical reactions, acids and bases, hydrocarbons, oxygen- and nitrogen-containing organic compounds, polymers, elements in the periodic table, etc.). The sample was selected to examine participants' views on specific chemistry-related activities that may serve as indicators of their potential giftedness in chemistry, as well as to assess their motivational characteristics for learning chemistry. Although these pre-service primary school teachers will not teach chemistry as a distinct subject following graduation, they will teach general science, which incorporates fundamental chemical concepts within the curriculum. Therefore, it is essential that they demonstrate sufficient motivation to learn chemistry and develop a meaningful understanding of its relevance. Moreover, they should be capable of perceiving and interpreting chemical phenomena in everyday contexts and of designing and implementing chemistry-related activities at an appropriate level for primary education.

Participation in the study was voluntary and anonymous. The study posed no risk or inconvenience to participants. Privacy and appropriate treatment were ensured throughout participation. Moreover, each participant had the right to withdraw from the study at any time. The instruments containing participants' answers were stored according to ethical guidelines for the purposes of the study.

The study was conducted in accordance with the Declaration of Helsinki and was reviewed and approved by the Ethics Commission of the Faculty of Education of the University of Ljubljana. Approval code 16/2024, on April 2nd, 2024.

3.2. Instruments

Three questionnaires were used to collect data: (1) questionnaire on motivation for learning chemistry adapted from Ryan and Deci,[20] (2) a questionnaire on intrinsic motivation for learning the chemistry triplet,[46] and (3) a questionnaire on gifted behavioural scores in chemistry.[32]

The questionnaire on students' motivation for learning chemistry is an adapted version of the Learning-Self-Regulation Questionnaire (SRQ-L),[22] which explores reasons why individuals engage in learning activities in specific settings. Both the original and adapted versions ask three general questions, each followed by four sub-questions, regarding students' motivation for learning chemistry. Responses are rated on a 5-point Likert scale (1 – absolutely not true, 2 – not true, 3 – partially true, 4 – true, 5 – completely true), as opposed to the 7-point scale used in the original version. The adapted version also includes seven additional statements related specifically to chemistry classes. Students rated their agreement with each statement using the same 5-point Likert scale. While the original questionnaire includes two subscales -autonomous regulation (representing intrinsic motivation) and controlled regulation (representing extrinsic motivation),[23] the adapted version used in this study also includes a subscale for amotivation. Accordingly, 5 statements measured autonomous motivation, 7 measured controlled motivation, and 3 statements assessed amotivation. In the current study, the Cronbach's alpha coefficient was .634, indicating that the reliability of the questionnaire is just below the .7 mark which is the recommended minimum level for reliability according to Pallant:[47]

The questionnaire on students' intrinsic motivation for learning different levels of chemical content presentations was developed by Devetak and Juriševič.[46] It includes 28 items divided into four subscales: (1) macroscopic, (2) submicroscopic, (3) symbolic, and (4) chemistry in general. Students rated their agreement on a 5-point Likert scale (1 – I completely disagree, 2 – I disagree, 3 – I am undecided, 4 – I agree, 5 – I completely agree). In the current study, the Cronbach's alpha coefficient was 0.628, indicating that the reliability of the questionnaire is just below the 0.7 mark which is the recommended minimum level for reliability according to Pallant.[47]

The internal consistency of both motivation scales was below the conventional 0.70 threshold. However, these results are consistent with the theoretical nature of the construct. Motivation is inherently multidimensional and heterogeneous, reflecting diverse domain-specific expressions rather than a single latent trait. As the scale is designed to capture a broad range of interests, lower inter-item correlations and a correspondingly lower Cronbach's alpha are expected and do not necessarily indicate poor measurement quality.

Students gifted behavioural scores were assessed using the questionnaire by Sumida and Ohashi.[32] This in-

strument includes 30 items rated on a 4-point Likert scale (1 – I strongly disagree, 2 – I disagree, 3 – I agree, 4 – I completely agree), through which students indicated their agreement with each statement. In the current study, the Cronbach's alpha coefficient was .923, indicating good internal consistency. [47]

3.3. Research design

Students' level of motivation was calculated according to their agreement with specific statements. Responses marked on the Likert-type scale were assigned to the corresponding subscale measured by each statement. After distributing the points, raw scores from each subscale were used to calculate the Relative Autonomous Index (RAI). The RAI was determined by first calculating the autonomous regulation and controlled regulation subscale scores, which were obtained by averaging the responses to the items within each subscale. The RAI was then derived by subtracting the controlled regulation subscale score from the autonomous regulation subscale score. The amotivation subscale was not included in the RAI calculation as the RAI reflects the degree to which an individual's motivation is self-determined (autonomous), whereas the amotivation scale assesses the absence of motivation. However, amotivation subscale scores were calculated by averaging the responses to the items within the subscale.[25]

The level of students' intrinsic motivation for learning chemistry content at different levels of representation (macroscopic, submicroscopic, and symbolic) was assessed based on their agreement with specific statements designed to measure intrinsic motivation at each respective level. Responses corresponding to each subscale were summed to obtain a total score representing the degree of intrinsic motivation for that particular level of content representation. Students were then divided into three groups (Table 1).

Students' gifted behavioural scores were assessed through their responses to statements designed to measure this construct. The total gifted behavioural score was obtained by summing their responses. Based on these scores, students were divided into three groups (Table 1)

Table 1. Criteria for dividing students into three groups.

Nr. of points	Groups of students
< ***M* – *SD***	Students with low level of intrinsic motivation for triple nature of chemical concepts/_gifted behavioural scores
< ***M* ± *SD*** >	Students with medium level of intrinsic motivation for triple nature of chemical concepts /_gifted behavioural scores
> ***M* + *SD***	Students with high level of intrinsic motivation for triple nature of chemical concepts/_gifted behavioural scores

In the questionnaire assessing intrinsic motivation for learning chemistry content at different representational levels, students scored on average at macroscopic level (M = 38.60, SD = 3.79), submicroscopic level (M = 38.86, SD = 4.00) and symbolic level (M = 36.26, SD = 3.60).

Accordingly, students were grouped into three categories (Table 2).

Table 2. Groups of students according to different level of intrinsic motivation for learning different levels of presentations of chemistry content.

Nr. of points	Groups of students
< 38.60 – 3.79	Students with low level of intrinsic motivation for learning macroscopic level of chemistry content
< 38.60 ± 3.79 >	Students with medium level of intrinsic motivation for learning macroscopic level of chemistry content
> 38.60 + 3.79	Students with high level of intrinsic motivation for learning macroscopic level of chemistry content
< 38.86 – 4.00	Students with low level of intrinsic motivation for learning submicroscopic level of chemistry content
< 38.86 ± 4.00 >	Students with medium level of intrinsic motivation for learning submicroscopic level of chemistry content
> 38.86 + 4.00	Students with high level of intrinsic motivation for learning submicroscopic level of chemistry content
< 36.26 – 3.60	Students with low level of intrinsic motivation for learning symbolic level of chemistry content
< 36.26 ± 3.60 >	Students with medium level of intrinsic motivation for symbolic level of chemistry content
> 36.26 + 3.60	Students with high level of intrinsic motivation for learning symbolic level of chemistry content

In the questionnaire measuring gifted behavioural scores, students achieved an average score of M = 64.36 (SD = 10.99). Based on these scores, students were divided into three groups (Table 3).

Table 3. Groups of students according to different level of gifted behavioural scores.

Nr. of points	Groups of students
< 64.36 – 10.99	Students with low level of gifted behavioural scores
< 64.36 ± 10.99 >	Students with medium level of gifted behavioural scores
> 64.36 + 10.99	Students with high level of gifted behavioural scores

3.4. Data analysis

The data collected through the questionnaires were transferred to Microsoft Excel, and statistical analyses were conducted using IBM SPSS Statistics software. The Kolmogorov-Smirnov test was applied to assess the distribution of the data. Specifically, normality of the distribution was tested for the results obtained from groups of students with different levels of intrinsic motivation for learning chemistry triplet as well as for their motivation and gifted behavioural scores. The Kolmogorov-Smirnov test indicated a non-normal data distribution ($p < 0.001$). This applied to both the questionnaire on students' gifted behavioural scores and their motivation, as well as to the data on the relationship between gifted behavioural scores and motivation for learning the chemistry triplet. As a result, the non-parametric Kruskal-Wallis test was used to examine statistically significant differences between groups. Post hoc multiple comparisons (contrast analysis) were conducted when the Kruskal-Wallis test identified statistically significant differences. Additionally, descriptive statistics were employed. The median was used to represent central tendency, while interquartile ranges (IQRs) were calculated to describe the variability in the data.

4. Results and discussion

The results are presented in accordance with the research questions outlined earlier. Findings are discussed within the framework of the research objectives to provide contextual interpretation.

4.1. Students' intrinsic motivation for learning chemistry triplet and their overall motivation (RAI) for learning chemistry.

The first research question addressed the statistically significant differences in motivation for learning chemistry among students with varying levels of intrinsic motivation for learning chemistry at the macroscopic, submicroscopic, and symbolic levels. The Kruskal-Wallis test revealed no statistically significant differences between groups of students with different levels of intrinsic motivation for learning chemistry at the macroscopic level and their RAI ($H = 0.191$; $p = 0.909$). Similarly, no statistically significant differences were found between groups of students with different levels of intrinsic motivation for learning chemistry at the submicroscopic level ($H = 0.350$; $p = 0.839$), nor at the symbolic level ($H = 1.364$; $p = 0.506$). However, when comparing median scores across the three representational levels, students reported the highest intrinsic motivation for learning chemistry at the macroscopic level (*Md* = 38.50; *IQR* = 36.00–41.00), followed by the submicroscopic level (*Md* = 37.00; *IQR* = 35.00–40.00). The symbolic level showed the lowest median intrinsic motivation score (*Md* = 36.00; *IQR* = 35.00–38.00). Next, students' amotivation was compared across groups with different levels of intrinsic motivation for learning chemistry on different levels of chemical presentation. The Kruskal-Wallis test revealed no statistically significant differences in amotivation among students with different levels of intrinsic motivation for learning chemistry at the macroscopic level ($H = 5.654$; $p = 0.059$). In contrast, statistically significant differences were found between students with different levels of intrinsic motivation for learning chemistry at the submicroscopic level ($H = 9.052$; $p = 0.011$) and between students with different levels of intrinsic motivation for learning chemistry at the symbolic level ($H = 7.218$; $p = 0.027$) in relation to their amotivation. Post-hoc analyses were conducted to identify statistically significant differences between pairs. At the submicroscopic level, students with low intrinsic motivation (*Md* = 30.00; *IQR* = 27.50–31.50; $n = 9$) differed significantly from those with medium intrinsic motivation (*Md* = 37.00; $n = 60$; *IQR* = 35.00–39.00; $U = 144.500$, $p = 0.023$), and high intrinsic motivation (*Md* = 42.00; $n = 11$; *IQR* = 41.00–43.00; $U = 12.000$, $p = 0.004$). At the symbolic level, students with low intrinsic motivation (*Md* = 30.00; *IQR* = 27.50–30.50; $n = 9$) also differed significantly from those with medium intrinsic motivation (*Md* = 37.00; $n = 59$; *IQR* = 35.00–38.00; $U = 125.500$, $p = 0.010$).

These findings suggest that students' RAI is not significantly associated with their intrinsic motivation across the different levels of the chemistry triplet. These results align with the findings of Juriševič et al.,[26] who also reported that students exhibit the lowest intrinsic motivation for learning chemistry at the symbolic level. However, results differ from those of Devetak and Glažar,[25] who found that students who are more motivated for chemistry in general tend to have higher level of intrinsic motivation to learn chemistry at the submicroscopic level. This pattern was not confirmed in the present study, as no significant differences were observed between groups of students with varying levels of intrinsic motivation at the submicroscopic level and their RAI. Furthermore, previous studies[20,14] noted that students' motivation can decrease when faced with complex and cognitively demanding tasks, such as submicroscopic representations.[2] While this study did not directly confirm that relationship, the finding that students showed the highest intrinsic motivation at the macroscopic level may be partially explained by this theory. One possible explanation for the higher intrinsic motivation observed at the macroscopic level is that instructional practices tend to emphasize macroscopic phenomena, making this level more familiar and less cognitively demanding for students.[46] Consequently, students may perceive this content as more accessible, which may mitigate the motivational decline associated with complex and abstract representations.[20]

4.2. Students' gifted behavioural scores and their motivation for learning chemistry

The second research question focused on the statistically significant differences in motivation for learning chemistry among students with different levels of gifted behavioural scores. The Kruskal-Wallis test revealed no statistically significant differences between groups of students with different levels of gifted behavioural scores and their motivation for learning chemistry (H = 4.563; p = 0.102). However, students in the group with the highest gifted behavioural scores showed a higher median motivation score (*Md* = 40.00; *IQR* = 39.00–44.00; n = 11), compared to students with a medium (*Md* = 38.00; *IQR* = 37.00–40.00; n = 55) and low (*Md* = 36.00; *IQR* = 33.00–38.25; n = 14) levels of gifted behavioural scores. In contrast, statistically significant differences were observed in students' amotivation between the groups. The Kruskal-Wallis test revealed statistically significant differences in amotivation between the students with different levels of gifted behavioural scores (H = 17.538; p < 0.001). Post hoc analysis further clarified these differences: students with low gifted behavioural scores (*Md* = 36.00; *IQR* = 33.00–38.25; n = 14) differed significantly from those with medium levels of gifted behavioural scores (*Md* = 38.00; n = 55; *IQR* = 37.00–40.00; U = 229.000, p = 0.018), and high levels of gifted behavioural scores (*Md* = 40.00; n = 11; *IQR* = 39.00–44.00; U = 15.000, p < 0.001). Additionally, students with medium levels of gifted behavioural scores (*Md* = 38.00; *IQR* = 37.00–40.00; n = 55) differed significantly from those with high levels of gifted behavioural scores (*Md* = 40.00; *IQR* = 39.00–44.00; n = 11; U = 112.500, p < 0.001).

These findings are consistent with several previous studies,[30,34,39] which also reported differences in motivation levels between gifted and non-gifted students. However, the results contradict the findings of Paz Baruch and Hazema,[40] who reported statistically significant differences in motivation between gifted and non-gifted students. One explanation for this discrepancy may lie in the conceptualization and measurement of giftedness. In the present study, giftedness was based on students' self-perceptions, whereas Paz Baruch and Hazema[43] identified gifted students using objective psychometric instruments. The use of perceived, rather than formally assessed giftedness may have influenced the results. Additionally, it is known that gifted students often prefer learning with models that support learning abstract chemical concepts.[1,20] However, there have been reports of a lack of learning models in chemistry teaching.[38] This may suggest that teachers are not employing instructional strategies that effectively foster motivation among gifted students when teaching the chemistry triplet. Another possible explanation could be the overemphasis on the macroscopic level in chemistry instructions.[32] If teaching practices rely too heavily on macroscopic explanations, gifted students may not be sufficiently challenged by tasks requiring higher-level cognitive engagement. As a result, their motivation may not be fully activated or supported.

4.3. Students' intrinsic motivation for learning on the different levels of chemical presentations and their gifted behavioural scores

The third research question deals with the statistically significant differences in gifted behavioural scores

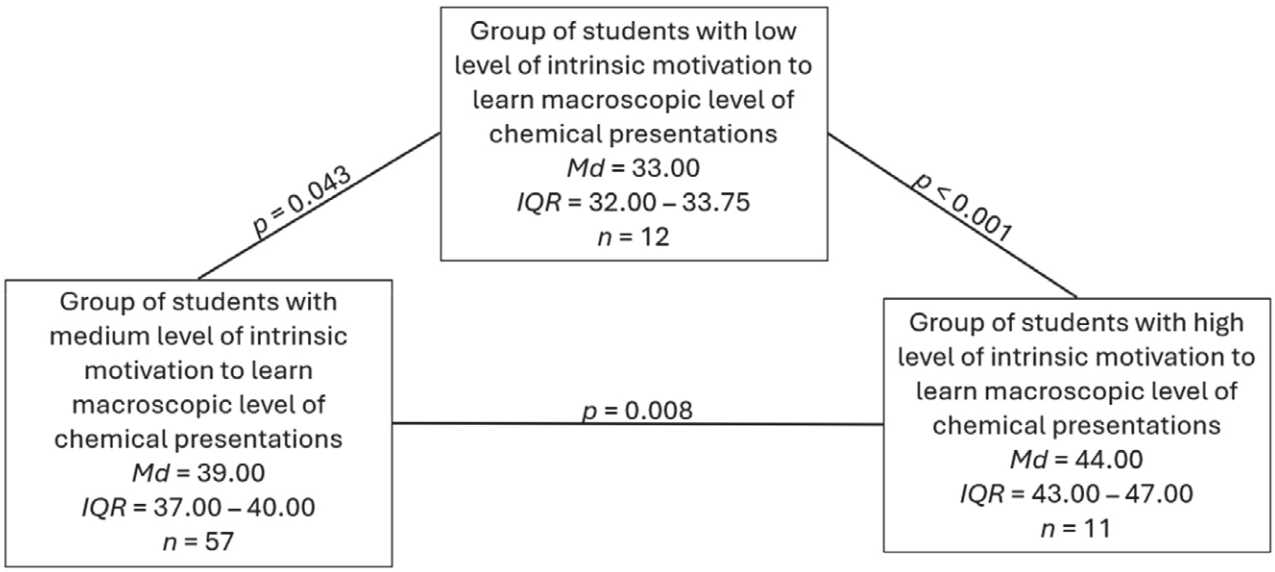


Figure 2. Statistically significant differences between levels of intrinsic motivation for learning chemistry at the macroscopic level of presentation and students' gifted behavioural scores. *Md* – median of points gathered by students on the questionnaire measuring their gifted behavioural scores; *IQR* – interquartile range of points; n – number of students in the specific group according to their intrinsic motivation for learning chemistry at the macroscopic level.

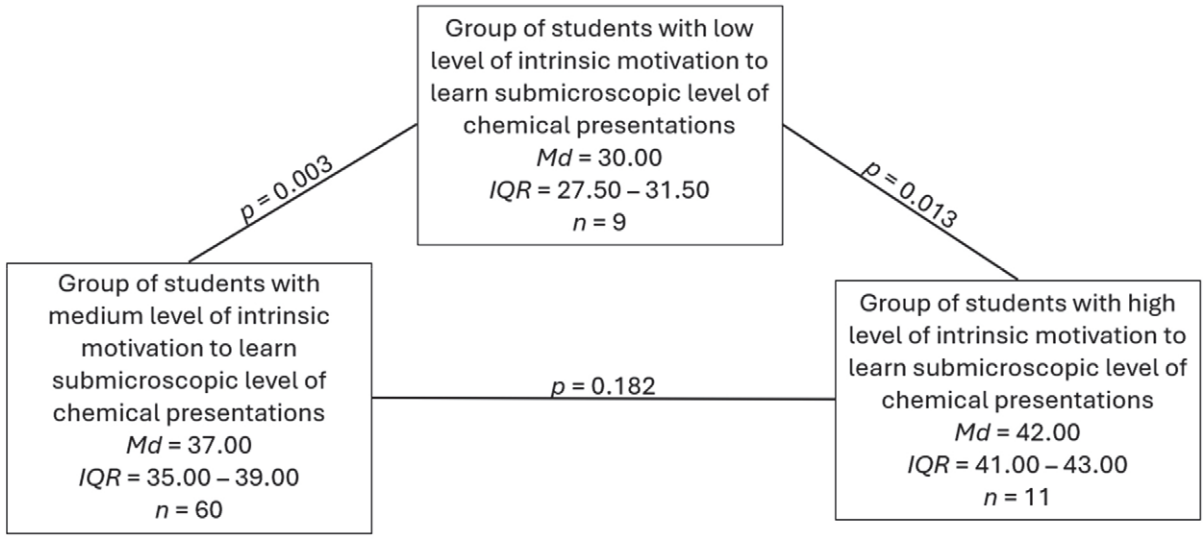


Figure 3. Statistically significant differences between levels of intrinsic motivation for learning chemistry at the submicroscopic level of presentation and students' gifted behavioural scores. *Md* – median of points gathered by students on the questionnaire measuring their gifted behavioural scores; *IQR* – interquartile range of points; *n* – number of students in the specific group according to their intrinsic motivation for learning chemistry at the submicroscopic level.

among students with different levels of intrinsic motivation for learning chemistry at the macroscopic, submicroscopic, and symbolic levels. The Kruskal-Wallis test revealed statistically significant differences in students' intrinsic motivation for learning chemistry at the macroscopic ($H = 15.910$; $p < 0.001$), submicroscopic ($H = 9.285$; $p = 0.010$) and symbolic ($H = 12.324$; $p = 0.002$) levels of chemical presentations in relation to their gifted behavioural scores. To further investigate these differences, post hoc Mann-Whitney tests were conducted to compare motivation scores between groups. Significant differences were found between all group pairs at the macroscopic level of presentations (Figure 2).

Furthermore, significant differences were also obtained between all group pairs at the symbolic level of presentation (Figure 3). However, when comparing pairs based on intrinsic motivation at the submicroscopic level of presentation, no significant difference was found between the group of students with medium levels of intrinsic motivation to learn chemistry at the submicroscopic

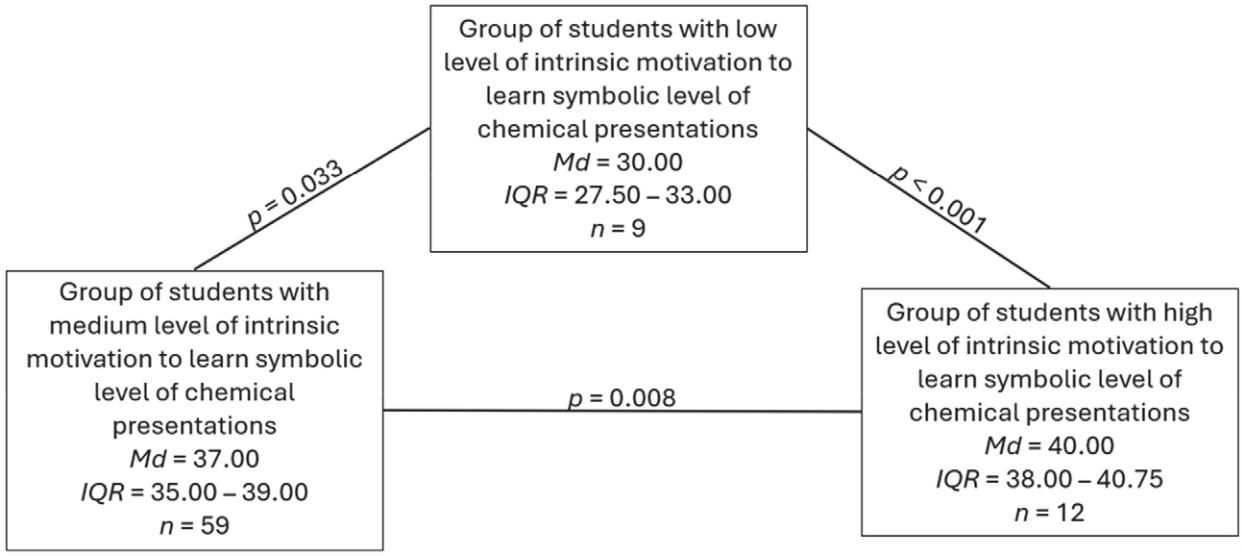


Figure 4. Statistically significant differences between levels of intrinsic motivation for learning chemistry at the symbolic level of presentation and students' gifted behavioural scores. *Md* – median of points gathered by students on the questionnaire measuring their gifted behavioural scores; *IQR* – interquartile range of points; *n* – number of students in the specific group according to their intrinsic motivation for learning chemistry at the symbolic level.

level and students with high levels of intrinsic motivation to learn chemistry at the submicroscopic level of presentation (Figure 4).

The results of this study are consistent with findings from previous research by Chen et al.[7], who reported that complex content, such as the triple nature of chemical phenomena, is often more comprehensible and engaging for gifted students, as they tend to find such content intellectually stimulating.[32] Gifted students typically seek challenges in learning,[5,38] which may explain their higher intrinsic motivation to engage with chemistry at all three levels of presentation. Similarly, Agaliotis and Kalyva[39] also found higher intrinsic motivation among gifted students, which aligns with the findings of the present study. One possible explanation is that gifted students benefit more from the use of models during instruction.[42] Models serve as critical visual tools in chemistry education, especially for representing chemical processes at the submicroscopic level.[4] Moreover, the use of various visualization tools can provide greater autonomy in the learning process, which is a key factor in fostering intrinsic motivation, particularly among gifted students.[1,32] This increased autonomy allows them to explore content more deeply and flexibly, enhancing their engagement with abstract concepts. Given their higher intrinsic motivation, gifted students may be better equipped to bridge the three representational levels in chemistry learning. Therefore, it is essential for teachers to promote students' self-perceptions of scientific aptitude, as this can play a crucial role in sustaining motivation, especially when students are working with complex and abstract content within the chemistry triplet.[1]

5. Conclusions

This study investigated the interrelationship between pre-service primary school teachers' overall motivation for learning chemistry (RAI), their intrinsic motivation for learning about the triple nature of chemical phenomena (macroscopic, submicroscopic, and symbolic levels), and their gifted behavioural scores in chemistry. The findings indicate that no statistically significant differences were found between students' RAI and their intrinsic motivation for learning the chemistry triplet, nor between their motivation and gifted behavioural scores. However, significant differences did emerge when intrinsic motivation for learning at different representational levels was analysed in relation to students' gifted behavioural scores.

Students showed the highest intrinsic motivation for learning chemistry at the macroscopic level, likely due to the more frequent use of macroscopic representations in instructional practice and their relative conceptual accessibility. The symbolic level elicited the lowest intrinsic motivation, aligning with existing literature indicating its abstract nature presents greater cognitive challenges. Interestingly, students with higher gifted behavioural scores demonstrated significantly greater intrinsic motivation across all three levels of chemical representation, suggesting that gifted behavioural scores may be a key factor in fostering motivation to engage with complex and abstract scientific content.

These findings underscore the importance of developing pedagogical strategies that both challenge and support students, particularly gifted individuals, in navigating the triple nature of chemical phenomena. Teachers should integrate diverse visual models and representations to enhance conceptual understanding and foster autonomy in learning – factors critical for maintaining motivation, especially among learners who identify as gifted. The use of new technologies such as augmented reality and virtual reality should also be considered in chemistry education, to augment learning on the submicroscopic level with visuals that allow students to immerse themselves in the world of molecules and atoms. Furthermore, teacher education programs must address motivational dynamics and equip pre-service teachers with didactic tools that promote both competence and interest across all levels of chemical representations. By doing so, they can better support the development of scientifically accurate mental models and improve learning outcomes for all students.

4.2. Limitations of the study

This study has several limitations that should be considered when interpreting the results. First, the sample was limited to pre-service primary school teachers from a single institution, which may restrict the generalizability of the findings to broader populations. Second, the use of self-report questionnaires introduces the possibility of social desirability bias and subjective interpretation, particularly regarding gifted behavioural scores, because objective measures of academic achievement or cognitive ability were not included. Objective measurements could provide a more comprehensive understanding of the relationship between motivation and giftedness. Finally, while the study focused on intrinsic motivation for the chemistry triplet, other motivational constructs such as interest, self-efficacy, or classroom environment were not examined and may also play important roles in chemistry learning and may be connected with students' giftedness for learning chemistry.

4.3. Future work

Future studies should aim to include larger and more diverse samples to improve generalizability. Since this study relied on students' gifted behavioural scores, future research should incorporate objective measures of cognitive ability or academic achievement. Longitudinal designs could provide insight into how motivation and gifted behavioural scores develop over time during teacher educa-

tion.

Intervention-based research is also recommended to test teaching strategies that utilize visual models and representations at all three levels of chemical concepts. Additionally, immersive technologies to present the submicroscopic level can be integrated into interventions. Also, qualitative approaches, such as interviews or focus groups, could deepen understanding of students' learning experiences and motivational drivers.

4.4. Acknowledgement

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Povzetek

Motivacija je pomemben dejavnik pri napovedovanju akademskih dosežkov študentov in višje ravni motivacije so bile ugotovljene pri nadarjenih študentih. Namen raziskave je preučiti odnos med motivacijo bodočih učiteljev razrednega pouka za učenje kemije, njihovo intrinzično motivacijo za razumevanje trojne narave kemijskih pojmov ter njihovimi rezultati na lestvici vedenjskih značilnosti nadarjenosti na področju kemije. V raziskavi je sodelovalo 80 študentov prvega letnika študijskega programa za razredni pouk, ki so izpolnili tri vprašalnike. Rezultati niso pokazali statistično značilnih razlik med splošno motivacijo študentov za učenje kemije (Relative Autonomous Index – RAI) in njihovo intrinzično motivacijo za učenje trojne narave kemijskih pojmov, prav tako ne med motivacijo in rezultati na lestvici vedenjskih značilnosti nadarjenosti. Ugotovljene pa so bile statistično značilne razlike med rezultati na lestvici vedenjskih značilnosti nadarjenosti in intrinzično motivacijo študentov na vseh treh ravneh predstavitve kemijskih pojmov, pri čemer so nadarjeni študenti izkazovali višjo motivacijo. Študenti so izkazali najvišjo intrinzično motivacijo za učenje na makroskopski ravni, najmanj pa so bili motivirani za učenje na simbolni ravni. Ugotovitve poudarjajo pomen prilagojenih učnih strategij, ki podpirajo tako nadarjene kot tudi nenadarjene študente pri razumevanju abstraktne narave kemijskih pojmov. Izboljšanje vizualizacije ter spodbujanje avtonomije pri učenju lahko prispevata k večji intrinzični motivaciji in boljšemu konceptualnemu razumevanju. Raziskava prav tako nakazuje, da rezultati na lestvici vedenjskih značilnosti nadarjenosti vplivajo na vključenost študentov pri obravnavi kompleksnih znanstvenih vsebin, kar poudarja potrebo po upoštevanju individualnih značilnosti učečih se v programih izobraževanja učiteljev.

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