

## **Student autonomy and its development in Physics or Chemistry class: beliefs of Lebanese Science High School teachers**

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### **ABSTRACT**

*The present paper aims to compare the beliefs of 8 Lebanese physics teachers and 8 Lebanese chemistry teachers, all of whom are teaching in the third year of secondary education, within the Life Sciences and General Sciences tracks. The study focuses on their characterization of the autonomous student and on the methods for developing student autonomy. To this end, semi-directive interviews were conducted with the 16 participants, exploring autonomy under two types: transversal autonomy and disciplinary didactic autonomy. Preliminary results highlight a convergence of teachers' beliefs, favoring the technical dimension for characterizing students' transversal autonomy. Regarding disciplinary didactic autonomy, a convergence of beliefs is observed around the technical and psycho-affective domains in identifying autonomous students. Finally, both groups of teachers emphasized the importance of conditions that may foster the psycho-affective and methodological domains of student's didactic autonomy.*

### **KEYWORDS**

*Transversal autonomy, disciplinary didactic autonomy, teachers' beliefs, Physics or Chemistry, Lebanon*

### **RÉSUMÉ**

*Ce texte a pour objectif de confronter les croyances de 8 enseignants libanais de physique et de 8 enseignants libanais de chimie, tous exerçant en classe de troisième année secondaire séries sciences de la vie et sciences générales. L'étude se focalise sur leur caractérisation de l'élève autonome et sur les conditions de développement de l'autonomie de leurs élèves. À cette fin, des entretiens semi-directifs ont été conduits auprès des 16 participants, explorant l'autonomie sous deux types : l'autonomie transversale et l'autonomie didactique disciplinaire. Les résultats préliminaires mettent en lumière une convergence des points de vue des enseignants, privilégiant la dimension technique pour la caractérisation de l'autonomie transversale des élèves. S'agissant de l'autonomie didactique disciplinaire, une convergence*

*des points de vue est observée autour des domaines technique et psycho-affectif dans l'identification des élèves autonomes. Enfin, les deux groupes d'enseignants ont souligné l'importance des conditions susceptibles de favoriser les domaines psycho-affectif et méthodologique de l'autonomie didactique disciplinaire des élèves.*

## **MOTS CLÉS**

*Autonomie transversale, Autonomie didactique disciplinaire, croyances des enseignants, Physique ou Chimie, Liban*

## **INTRODUCTION**

For years, student autonomy has become a recurring theme in various fields of research, including educational sciences (Denouël, 2017; Dethoor et al., 2021; Guo, 2019) and disciplinary didactics (El Bilani et al., 2007; El Hage et al., 2021; Gueudet & Lebaud, 2019). In the school context, according to previous studies (El Hage, 2024), the promotion and development of autonomy in physics and chemistry stem from the teacher's role.

The Lebanese institutional context currently spans 15 years and is divided into 4 cycles: kindergarten, primary cycle, complementary cycle, and the secondary cycle. The final year of secondary school includes four orientations, two of which are considered scientific: life sciences (LS) and general sciences (GS). In Lebanon, every Physics high school teacher holds a Bachelor's degree, in physics, and does not teach chemistry as in some other countries. The notion of autonomy explicitly appears in the science teaching curricula (physics, chemistry, and biology) across primary, middle, and secondary cycles, where one of the general objectives is 'Promoting autonomy and teamwork'. It is important to note that there is no specific description or definition of autonomy developed by the educational institution. Teachers responsible for promoting their students' autonomy in physics or chemistry therefore completely lack information on what it means to be an autonomous student in these fields. Similarly, they have no instructions on the methods to use to foster the development of autonomy in their students. This study aims to examine how physics or chemistry teachers in Lebanese public high schools define an autonomous student and how they declare they promote the development of their student's autonomy in LS and GS classes.

## **REVIEW OF LITERATURE**

Several studies in the Didactics of physics and didactics of chemistry have examined definitions of autonomy. Many recent works (Boilevin et al., 2021; El Hage, 2023, 2024; El Hajjar et al., 2023; Le Bouil, 2022) build on Alberio's framework (2004), which conceptualizes autonomy not as a global notion but as a set of specific competencies articulated across domains such as technical, informational, methodological, social, cognitive, metacognitive, and psycho-affective, which can be fostered through targeted learning activities and tasks. These studies also draw on distinctions proposed by Gueudet and Lebaud (2019) in the field of mathematics education, who differentiated pedagogical autonomy from didactic autonomy, subdividing didactic autonomy into knowledge mobilization and acquisition. Further refinements include the distinction between specific and generic didactic autonomy (El Hage & Maigret, 2022).

Comparing the views of physics-chemistry teachers and mathematics teachers in France, Boilevin et al. (2021) found complementary but not identical definitions, with digital tools fostering autonomy more for mathematics teachers than for the interviewed physics-chemistry teachers.

Another French study by El Hage et al. (2021) with physics-chemistry teachers and a school inspector revealed that their expectations regarding the autonomous student fall under pedagogical autonomy (highlighting peer cooperation) and didactic autonomy (actively searching for and sorting information and being motivated to solve exercises).

Inspired by this work, El Hajjar et al. (2021) transposed it to the Lebanese context by interviewing 3 physics teachers and a pedagogical counselor. They observed institutional convergences and divergences. Regarding pedagogical autonomy, interviewees described the autonomous student in terms of four domains of autonomy: technical (mastery of digital tools and platforms), methodological (knowing when and how to seek support from the teacher), and social and psycho-affective (motivation to learn and cooperation with peers). Regarding didactic autonomy, the interviewees reported that the autonomous student in physics demonstrates aspects related to three domains of autonomy: psycho-affective (motivation to learn topics related to everyday life), cognitive (using mental operations to build electrical circuits from diagrams and formulating hypotheses during lab work), and methodological (organizing their own work to conduct experiments while effectively mobilizing available physics resources).

Research highlights the importance of autonomy in practical work. For instance, Khanfour-Armalé (2008, cited in El Hage, 2023) describes it as students working independently during laboratory sessions, involving manipulation, peer interaction, and report writing. Robertson and Gail Jones (2013) emphasize contextual constraints such as material access, financial resources, while Le Bouil et al. (2019) point to teacher–student interactions, work habits, clarity of instructions, and disciplinary specificities as factors shaping student’s autonomy.

In summary, the literature in chemistry didactics reveals that autonomy is a complex and multidimensional notion. Conceptual frameworks, particularly Albero’s (2004), highlight autonomy as a set of diverse competencies, while other authors differentiate between pedagogical autonomy (linked to cooperation, classroom practices, and teacher–student interactions) and didactic autonomy (focused on knowledge mobilization and acquisition). Studies (Le Bouil et al., 2019; Robertson & Gail Jones, 2013) also emphasize the role of practical work, where reduced teacher intervention, peer interaction, and task management allow autonomy to manifest, although its development is often constrained by material, institutional, and assessment-related factors. Comparative research (Boilevin et al., 2021) shows both disciplinary specificities and shared dimensions across contexts, underlining that autonomy cannot be reduced to a single definition.

In line with many studies (Ciekanski, 2019; Denouël, 2017; El Hage, 2023; Jayawardena et al., 2017), we consider that to initiate students into autonomous work, teachers must adopt specific approaches, placing the student at the center of the teaching-learning process so that they construct their own path to knowledge. From this perspective which emphasizes the teacher’s role in fostering student autonomy, the literature identifies a framework called “autonomy support” (or “autonomy supportive teaching”, “motivational style” etc.). According to Maldonado et al. (2019, p. 2, cited in López-Belmonte & Parra-González, 2022), autonomy support encompasses “actions or instructions aimed at identifying, encouraging, and developing students’ internal motivational resources, such as their interests, preferences, goals, and psychological needs”. This motivational approach leads teachers to offer choices regarding work pace and task difficulty (Patall et al., 2018), thereby developing students’ internal resources so that they perceive themselves as initiators of their actions (Patall & Zambrano, 2019). This “motivating style” contrasts with a controlling style in which the teacher’s own interests and values serve as the starting point, by facilitating the student’s intrinsic motivation by building on their individuality (Maldonado et al., 2019 cited in López-Belmonte & Parra-González, 2022). Flünger et al. (2019) specify that autonomy support

involves offering choices to students, asking them to justify their decisions, and using informative language.

Student autonomy and its development have been widely studied in various countries. In the Lebanese context, where high school physics and chemistry teachers are expected to foster student autonomy, no large-scale study has yet addressed this issue. Acknowledging that autonomy develops over time, the present study does not adopt a longitudinal perspective; rather, it draws on teachers' self-reported accounts. Its aim is to examine how Lebanese public high school physics and chemistry teachers define an autonomous student in LS and GS classes and how they believe they promote the development of student autonomy in their teaching practice.

## FRAMEWORK

In this study, we adopted a two-pronged conceptual framework. The first addresses teachers' beliefs, particularly the definition proposed by Pajares (1992), since it's the most cited in research (El Hajjar, 2025). It is stated as follows: "an individual's judgment of the truth or falsity of a proposition, a judgment that can only be inferred from a collective understanding of what human beings say, intend, and do" (Pajares, 1992, p. 316). As such, teachers' discourse constitutes a relevant entry point for accessing their beliefs, since it reflects their intentions and reasoning, even when not directly observable. The second framework is largely inspired by the existing literature on student autonomy. This is the AtA2d framework, developed by El Hage (2024), which, to our knowledge, is the only framework that allows for the characterization of an autonomous student in the physics classroom. Taking into consideration Albero's 7 domains of autonomy (2004), it is an analytical framework comprising "Transversal Autonomy," which covers elements common to all disciplines, and "Disciplinary Didactic Autonomy," which is specific to the epistemological dimensions of the physics and linked to teaching, learning, and study tasks within that context. This includes:

- *Modeling relationships*, which are foundational to the development of knowledge in physics and central to the teaching of this discipline (Tiberghien, 1994). These relationships allow for explaining, interpreting, and predicting phenomena
- *The semiotic aspect*, enabling the communication of knowledge elements in a physics class (Bécu-Robinault, 2015; El Hage & Buty, 2014). Indeed, physicists use different forms of communication verbal, symbolic, iconic, and mathematical to express their ideas (Halloun, 2004).

Table 1 presents the AtA2d analytical framework, structured into 4 columns. The first column identifies the autonomy domain, while Columns 2 and 3 present indicators<sup>1</sup> used to characterize a student's transversal or disciplinary didactic autonomy at a given moment. Column 4 provides illustrative examples of expected student behaviors in physics, specified according to task type (El Hage, 2024) and related to the themes taught in the third year of secondary education in Lebanon.

The literature on student autonomy in chemistry (El Hajjar, 2025) has not provided a clear characterization of the autonomous high school student in chemistry. This is why we

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<sup>1</sup> The indicators are inferred from observable manifestations of students. For example, in the metacognitive domain, they may include mental operations revealed through students' verbal explanations, written decision-making steps during experimental tasks, or other behaviors that reflect planning, monitoring, and evaluation of their own learning.

propose adaptations of the AtA2d analytical framework, originally for physics, to characterize what an autonomous student in chemistry is. Since the domains of transversal autonomy are the same across disciplines, particularly in physics and chemistry, we focus on indicators that characterize the domains of disciplinary didactic autonomy exclusively in chemistry class.

**TABLE 1**

*Indicators for characterizing the domains of student autonomy (At and A2d) during activity completion, with examples in physics to be specified according to task type, according to El Hage (2024)*

| <b>Domains of Autonomy</b> | <b>Indicators of Transversal Autonomy</b>                                                                                              | <b>Indicators of Didactic Autonomy</b>                                                                                                                                                                                                         | <b>Examples in Physics (scientific third year of secondary class in Lebanon)</b>                                                                                                                                                                                                                                           |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Technical</b>           | Mastery of digital technologies used and ability to adapt to the diversity of tools and supports.                                      | Extracting information on measurable quantities. Mastery of digital tasks (use of software/applications in physics) or experimental equipment (measuring instruments, etc.). Mastery of mathematical concepts such as vectors and derivatives. | The student is able to draw velocity vectors and the sum of two momentum vectors (before and after collision). The student is able to change the trigger duration of the air-cushion table's self-recording system.                                                                                                        |
| <b>Informational</b>       | Mastery of documentary research tools; knowing how to search for and find information.                                                 | Researching and processing information on dedicated physics websites, course materials, textbooks, etc. Identification of the nature of the information.                                                                                       | The student is able to extract information on the momentum vectors of two colliding objects from a recording showing their trajectories.                                                                                                                                                                                   |
| <b>Methodological</b>      | Organization of one's work in class or at home, taking into account objectives and research constraints.                               | Organization of one's physics activity over time. Implementation of an experimental protocol provided by the teacher. Implementation of a problem-solving approach. Proposal of a protocol with steps.                                         | In applying the principle of conservation of momentum, the student chooses a Galilean reference frame, defines the system and its components, establishes the balance of forces acting on the system, and describes the momentum of the system's constituents before and after the collision based on the questions asked. |
| <b>Social</b>              | Collaboration with other students and/or with the teacher; development of attitudes of empathy, openness, and tolerance towards peers. | Exchange and cooperation with other students regarding a physics situation. Appropriate solicitation of the teacher in physics class.                                                                                                          | The student collaborates with peers to conduct experiments and uses shared results during a practical session on an air-cushion table.                                                                                                                                                                                     |
| <b>Cognitive</b>           | Individual aspect of constructing a work strategy; creating links between new elements                                                 | Reinvestment of previously learned knowledge in physics to solve a task on another                                                                                                                                                             | The student determines whether a collision is elastic or inelastic, determines trajectories                                                                                                                                                                                                                                |

|                         |                                                                                                             |                                                                                                                                                                            |                                                                                                                                                                                                           |
|-------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         | and stabilized elements in representations.                                                                 | program topic. Establishing links between the world of objects/events and the world of theories/models. Use of varied mental operations related to disciplinary knowledge. | after collision, explains motion using Newton's cradle and the principle of conservation of momentum, and provides a physical interpretation of calculated momentum values.                               |
| <b>Metacognitive</b>    | Reflective activities on actions undertaken and on the efficiency of chosen learning modalities.            | Ability to self-assess and use errors to develop strategies in physics. Awareness of one's own strategies and monitoring results.                                          | When solving an exercise where the sum of external forces is zero, the student corrects his reasoning if conservation of momentum is not found and identifies difficulties in interpreting system motion. |
| <b>Psycho-affective</b> | Self-esteem; willingness to answer questions in class and show work; intrinsic and/or extrinsic motivation. | Taking initiative in problem solving or experimental activities. Intrinsic and/or extrinsic motivation for learning physics and understanding.                             | The student persists in solving exercises despite contextual difficulties and is motivated to learn mechanics and momentum concepts due to aspirations such as becoming a mechanical engineer.            |

As shown in the table 2, the content of the second column was inspired by research in the epistemology of chemistry. In particular, it draws on work distinguishing chemical change from chemical reaction as a conceptual and symbolic model used to represent and explain this change (Canac & Kermen, 2016; Kermen, 2018). It also incorporates Barlet's (1999) analysis of the macroscopic–microscopic dialectic.

As for column 3, it proposes examples of behaviors allowing one to infer disciplinary didactic autonomy in chemistry in LS and GS classes in Lebanon, specifying them for two particular themes (kinetic factors, acid-base titration).

**TABLE 2**

*Examples indicating disciplinary didactic autonomy in chemistry for students in LS and GS classes in Lebanon*

| <b>Domains of Autonomy</b> | <b>Disciplinary Didactic Autonomy (A2d) in Chemistry</b>                                                                     | <b>Examples related to the teaching of chemical reactions (kinetic factors, acid–base titration, etc.) in the scientific third year of secondary class in Lebanon</b>                                                                                                                                                                                     |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Technical</b>           | Mastery of digital tasks (chemistry data acquisition software) or experimental equipment (use of glassware, pH meter, etc.). | The student demonstrates mastery in using glassware such as a volumetric flask or a graduated cylinder to perform precise volume measurements. The student prepares a diluted solution from a stock solution, represents graphically the evolution of pH as a function of the volume of titrant added, and uses simulations (e.g., Avogadro) to visualize |

|                         |                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                            |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                         |                                                                                                                                                                                                                             | the chemical reaction model at the microscopic level.                                                                                                                                                                                                                                                      |
| <b>Informational</b>    | Research and processing of information from dedicated chemistry websites, chemistry textbooks, and product labels (e.g., toxicity information). Extraction of information from the periodic table.                          | By reading the labeling of a strong acid or strong base, the student identifies potential hazards and harmful effects on health or the environment. Based on a document, the student selects appropriate molecular or developed formulas of strong acids and bases according to task-specific criteria.    |
| <b>Methodological</b>   | Organization of the resolution of a theoretical or experimental problem in chemistry. Implementation of an experimental protocol provided by the teacher. Adoption of a systematic problem-solving approach.                | In a problem related to the extent of a chemical reaction, the student identifies reactants and products, writes and balances the reaction equation, calculates initial amounts of substances with correct units and significant figures, and constructs a reaction progress table to answer the question. |
| <b>Social</b>           | Exchange and argumentation among students regarding the study situation to support knowledge construction in chemistry. Appropriate solicitation of the teacher.                                                            | The student exchanges with peers to detect potential errors during the implementation of an experimental procedure, discusses the choice of appropriate equipment for an acid–base titration, and communicates results orally using appropriate symbolic and scientific language.                          |
| <b>Cognitive</b>        | Conception of a complete experimental procedure without a provided protocol. Establishment of links between macroscopic and microscopic levels of chemical change. Representing a chemical reaction by a reaction equation. | The student distinguishes between chemical change and chemical reaction, interprets a chemical equation at both macroscopic and microscopic levels, and selects the appropriate formula for calculating the amount of substance based on the physical state (solid, liquid, gas).                          |
| <b>Metacognitive</b>    | Regulation based on the analysis of encountered situations. Detection and correction of errors during manipulation. Ability to self-assess and use errors to develop strategies.                                            | The student detects an error such as the lack of pH-meter calibration before titration and repeats the titration correctly to precisely determine the equivalence point of the acid–base reaction.                                                                                                         |
| <b>Psycho-affective</b> | Willingness to make predictions and propose hypotheses orally or in writing without fear of error. Perseverance and continued engagement despite difficulties related to handling chemical products.                        | The student continues to engage in chemistry practical sessions and handles chemical substances despite difficult contexts (e.g., Beirut port explosion). He verifies kinetic factors despite fear of toxicity and show motivation to learn chemistry due to aspirations to become a pharmacist.           |

### ***Research problem and research questions***

Grounded in the AtA2d framework and taking into account the notion of teachers' beliefs, the present study investigates how Lebanese high school physics and chemistry teachers define and report fostering student autonomy in LS and GS classes. The literature in physics and chemistry didactics shows that student autonomy is a complex, multidimensional concept, encompassing transversal competencies (e.g., work organization, cooperation, use of tools) and disciplinary didactic competencies (e.g., mobilization and acquisition of discipline-specific knowledge) (El Hage et al., 2021; Le Bouil et al., 2019). Several studies also emphasize that the development of autonomy depends on teaching practices as well as material, institutional,

and motivational conditions, such as offering students choices, supporting their intrinsic motivation, managing practical work, and structuring teacher–student interactions (Flünger et al., 2019; Patall & Zambrano, 2019; Robertson & Gail Jones, 2013). Building on these findings, the study addresses two complementary dimensions: (1) the characterization of students' autonomy and (2) the self-reported support provided by teachers to develop this autonomy. These dimensions guided the formulation of the following research questions:

1. What are the beliefs of Lebanese physics teachers and chemistry teachers regarding the criteria that characterize their students' transversal autonomy in LS and GS classes?
2. What are the beliefs of Lebanese physics and chemistry teachers regarding the criteria that characterize their students' disciplinary didactic autonomy in LS and GS classes?
3. According to Lebanese physics and chemistry teachers in LS and GS classes, which domains of transversal autonomy do they believe they develop in their students?
4. According to Lebanese physics and chemistry teachers in LS and GS classes, which domains of disciplinary didactic autonomy do they believe they develop in their students?

## MATERIAL AND METHODS

### *Data collection*

Given the particularly challenging conditions under which this research was conducted—most notably prolonged teachers' strikes that made classroom observations impossible—the study adopted a qualitative approach to investigate teachers' beliefs about student autonomy, relying primarily on self-reported accounts. Accordingly, declarative data collected through semi-structured interviews with 8 physics teachers and 8 chemistry teachers served as the main source for inferring these beliefs.

For chemistry, the interviewees included 6 women and 2 men, with 2 contract teachers and 5 permanent/tenured teachers. For physics, there were 3 men and 5 women, also comprising 2 contract teachers and six permanent/tenured teachers. Each teacher practiced in a different governorate. All participants took part in the interviews voluntarily, after indicating in the questionnaire their consent to participate. All the interviews were with an average duration of 30 minutes to one hour, were conducted via videoconference between December 2023 and February 2024. Before the interviews took place, we asked participants to send us a document presenting a session they had conducted, in which they believed their students demonstrated autonomy. Given that the teachers were under significant time constraints and had limited availability for the interviews, we chose to focus the interview guide on two main questions: *How would you describe your autonomous student in this session?* and *What did you do to foster student autonomy during this session?*

### *Data analysis*

The interviews were transcribed and analyzed using two complementary methods: lexicometry and thematic content analysis. The combination of lexicometry and thematic content analysis was chosen to provide an objective overview of teachers' discourse while yielding a deeper understanding of their beliefs about autonomy and its promotion in physics and in chemistry classes.

The first method is exploratory, was carried out with the IRaMuTeQ software, using basic word frequency analysis and descending hierarchical classification (DHC). A basic textual analysis was conducted to identify the most frequent words and lexical patterns in the corpus. (DHC) was then applied to organize text segments into homogeneous lexical classes

based on word co-occurrences; the results were visualized through dendrograms generated by the software.

The second, thematic analysis was carried out through two analytical steps, following El Hage's (2021) approach, in order to deepen the interpretation of the interview data. These steps are described below.

#### *First step of the thematic analysis: microscopic-level analysis of the interview data*

The 16 interview transcripts (physics and chemistry) were coded using the seven domains of the two AtA2d frameworks as analytical categories. Since the research questions focus on how teachers characterize autonomous students according to the AtA2d domains (questions 1 and 2) and on how they report fostering transversal or disciplinary didactic autonomy (questions 3 and 4), the transcripts were analyzed according to two main aspects: (1) the characteristics of autonomous students, and (2) the conditions that support the development of their autonomy. All statements were further classified according to the two forms of autonomy defined within the frameworks: disciplinary didactic and transversal autonomy.

Coding focused on 2 main aspects: (1) the characteristics of autonomous students, and (2) the conditions that support the development of student autonomy. Statements were classified according to the 2 forms of autonomy defined within the framework: disciplinary didactic autonomy and transversal autonomy.

#### *Characteristics of autonomous students*

Statements referring to the characteristics of autonomous students were identified and coded according to the AtA2d framework. For example, the statement "*The student can draw momentum vectors for two colliding systems before and after the collision*" was coded as disciplinary didactic autonomy within the technical domain, as it reflects a physics-specific technical skill. In contrast, the statement "*The student cooperates with classmates*" was coded as transversal autonomy within the social domain, as it refers to interactions with peers that are not specific to a particular discipline.

#### *Conditions supporting the development of student autonomy*

Statements referring to conditions that foster autonomy were coded separately. Examples include: "*The teacher provides students with the necessary materials to conduct a chemistry experiment in the lab*". This statement was coded as a condition that support the methodological domain in the disciplinary didactic autonomy, as it refers to a teaching condition that enables students to carry out the different stages of an experimental procedure. In contrast, the statement "*The teacher encourages students to work collaboratively in small groups*" was coded as transversal autonomy within the social domain, as it promotes cooperation and peer interaction regardless of the discipline.

The identification described in the previous paragraph is reformulated into defining elements of transversal or didactic autonomy; these elements correspond to units the size of a simple sentence. To this end, drawing on the concept of *facets of knowledge* (Minstrell, 1992), we define the following:

Autonomy facet (transversal or didactic): any element in teachers' discourse that relates to student autonomy. In our study, following Tiberghien (2012), a statement is associated with an autonomy facet in so far as the researcher considers it to convey the same meaning. We chose to reformulate the facets for greater clarity; all our facets begin with the phrase "*the student*". The statements and associated facets are summarized in tables 3 and 4.

Condition of autonomy: any element in teachers' discourse on which they declare can rely to foster the development of students' transversal or didactic autonomy. All

conditions begin with the phrase “*the teacher*”. The identified conditions are presented in tables 5 and 6.

**TABLE 3**

*Characterizing student autonomy in Physics through the cross-analysis of the 7 domains of At and A2d: examples and associated facets from teachers' discourse*

| Domains of Autonomy     | Transversal Autonomy (At)                                                                                                   | Facet (At)                                                                 | Disciplinary Didactic Autonomy (A2d)                                                      | Facet (A2d)                                                                                                      |
|-------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|
| <b>Technical</b>        | "This generation of students loves and is very skilled with everything related to technology, such as PowerPoint and Word". | The student masters' generic digital tools used across school disciplines. | "The students independently use the Sky Map app; they handled the tool very well".        | The student mobilizes a digital application (Sky Map) to support the learning of planetary positions in physics. |
| .....                   | ....                                                                                                                        | ....                                                                       | ....                                                                                      | ....                                                                                                             |
| <b>Psycho-affective</b> | "The student is self-confident and is not afraid to express his ideas in front of classmates".                              | The student shows self-confidence and dares to express his ideas in class. | "The student wants to become an engineer, which is why he is motivated to learn physics". | The student is motivated to learn physics because he aspires to become an engineer.                              |

**TABLE 4**

*Characterizing student autonomy in Chemistry through the cross-analysis of the 7 domains of At and A2d: examples and associated facets from teachers' discourse*

| Domains of Autonomy     | Transversal Autonomy (At)                                                                       | Facet (At)                                                                          | Disciplinary Didactic Autonomy (A2d)                                                                                  | Facet (A2d)                                                                                         |
|-------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| <b>Technical</b>        | "I always see them taking photos on their phones and making videos using apps on their phones". | The student masters generic digital tools used across school disciplines.           | "They know how to use lab glassware needed for titrating a strong acid with a strong base".                           | The student masters the use of lab glassware needed for titrating a strong acid with a strong base. |
| .....                   | ....                                                                                            | ....                                                                                | ....                                                                                                                  | ....                                                                                                |
| <b>Psycho-affective</b> | "The student takes initiative despite the difficulties encountered".                            | The student shows self-confidence. The student dares to express his ideas in class. | "I remember Anthony; he was persistent when solving problems related to the limiting reagent in a complete reaction". | The student is persistent in solving problems about the limiting reagent in a complete reaction.    |

**TABLE 5**

*Developing student autonomy in Physics through the cross-analysis of the 7 domains of At and A2d: examples and associated conditions from teachers' discourse*

| Domains of Autonomy | Transversal Autonomy (At) | Condition to foster (At) | Disciplinary Didactic Autonomy (A2d) | Condition to foster (A2d) |
|---------------------|---------------------------|--------------------------|--------------------------------------|---------------------------|
|---------------------|---------------------------|--------------------------|--------------------------------------|---------------------------|

|                         |                                                                                                                                                                  |                                                                                             |                                                                                                                                      |                                                                                                                                |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>Technical</b>        | "At the beginning of the pandemic, I provided a brief reminder on how Microsoft Teams functions so the students did not encounter any difficulties in using it". | The teacher gave a short reminder on how Microsoft Teams works before the students used it. | "I always introduce mathematical prerequisites related to vector representation before starting the lesson on momentum".             | The teacher always introduces the mathematical prerequisites for vector representation before starting the lesson on momentum. |
| ....                    | ....                                                                                                                                                             |                                                                                             | ....                                                                                                                                 |                                                                                                                                |
| <b>Psycho-affective</b> | "I encourage students to express their ideas in front of their classmates".                                                                                      | The teacher encourages students to share their ideas in front of the class.                 | "I always relate the concept of elastic collisions to collisions between billiard balls to motivate students to learn this concept". | The teacher always relates the concept of elastic collisions to billiard ball collisions to motivate students to learn it.     |

**TABLE 6**

*Developing student autonomy in Chemistry through the cross-analysis of the 7 domains of At and A2d: examples and associated conditions from teachers' discourse*

| <b>Domains of Autonomy</b> | <b>Transversal Autonomy (At)</b>                                          | <b>Condition to foster (At)</b>                                                    | <b>Disciplinary Didactic Autonomy (A2d)</b>                                                                             | <b>Condition to foster (A2d)</b>                                                                                                          |
|----------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Technical</b>           | "I ask them to make PowerPoint presentations".                            | The teacher asks students to create PowerPoint presentations.                      | "I ask students to prepare solutions with different concentrations".                                                    | The teacher asks students to prepare solutions with different concentrations.                                                             |
| ....                       | ....                                                                      |                                                                                    | ....                                                                                                                    |                                                                                                                                           |
| <b>Psycho-affective</b>    | "I give a clear talk about errors to dispel any fear caused by mistakes". | The teacher gives a clear talk about mistakes to remove any fear caused by errors. | "I show them the value of doing laboratory experiments by highlighting the macroscopic aspects of chemical substances". | The teacher shows students the value of performing laboratory experiments by highlighting the macroscopic aspects of chemical substances. |

As we can see in tables 3 and 4 and tables 5 and 6, reformulated facets and conditions faithfully reflect what the interviewers expressed during the interviews.

#### *Second step of the thematic analysis: mesoscopic-level analysis of the interview data*

Following Tiberghien (2012), we grouped the facets and the conditions supporting development of student's autonomy within the same domain of autonomy into notional groups (see Tables 7, 8). Within an autonomy domain, a notional group refers to a coherent set of facets or conditions that convey the same underlying meaning. Each autonomy domain may include several notional groups.

**TABLE 7**

*Grouping of two facets related to the methodological domain of transversal autonomy for a Physics teacher into a notional group*

| Domain                | Facets                                                                                                                                                                                                                         | Notional Group                                                        |
|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Methodological</b> | <ul style="list-style-type: none"> <li>• The student organizes his work at his own pace.</li> <li>• The student organizes his work to achieve learning objectives set by the teacher, using self-correction sheets.</li> </ul> | Organizing one's own work according to objectives set by the teacher. |

**TABLE 8**

*Grouping of two conditions related to the psycho-affective domain of didactic disciplinary autonomy for a Chemistry teacher into a notional group*

| Domain                  | Conditions                                                                                                                                                                                                                                 | Notional Group                                                                                             |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|
| <b>Psycho-affective</b> | <ul style="list-style-type: none"> <li>• The teacher asks the students why it is important to keep medicines at a cold temperature.</li> <li>• The teacher asks the students to suggest ways to safely store medicines at home.</li> </ul> | Fostering students' interest and motivation for learning chemistry through connections with everyday life. |

## RESULTS

### *Teachers' beliefs about the characterization of autonomous students in Physics or Chemistry classes*

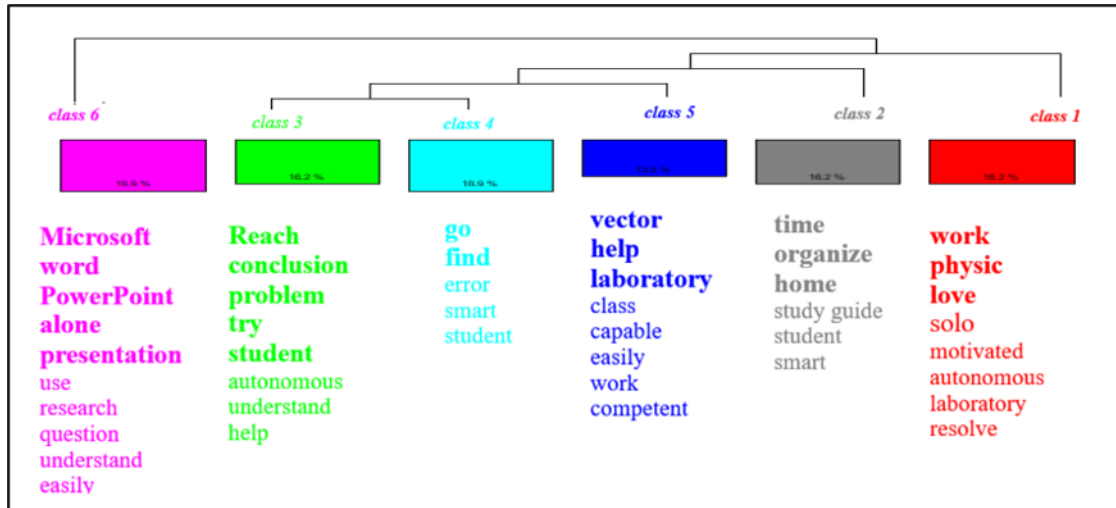
As shown in Figure 1, the lexicometric analysis, particularly the (DHC), groups the physics interviewees' responses into six categories. The first focuses on the development of positive feelings and motivation for laboratory work; the second concerns time management; the third relates to cognitive abilities; the fourth refers to error detection; the fifth involves technical skills related to mathematics; and the sixth concerns digital technical skills. Based on the content and dominant themes of each category, category 1 appears to correspond to the psycho-affective domain; categories 3 and 4 appear linked to the cognitive domain; categories 5 and 6 seem to correspond to the technical domain; and category 2 appears to pertain primarily to the methodological domain, all within the AtA2d framework. The strong separation of Class 6 from the other classes indicates that the lexical field related to digital tools (e.g., Microsoft Word, PowerPoint, presentation, research) forms a distinct cluster in the corpus. The words in this class co-occur frequently among themselves but rarely with those of the other classes.

While the lexicometric analysis highlights the main lexical classes structuring teachers' discourse, the thematic analysis complements this approach by examining the content of the interviews in greater depth, through the identification of facets and notional groups related to the domains of autonomy within the AtA2d framework. We now turn to the results of the thematic analysis.

In terms of transversal autonomy, the thematic analysis of the facets and the notional groups derived from the interviews revealed that all 8 teachers referred to elements related to the technical domain. The grouping of these facets led to the identification of a common

notional group across participants, namely “mastering the technologies used, particularly software such as Microsoft Office”. According to all participants, an autonomous student demonstrates strong proficiency in the use of these digital tools.

**FIGURE 1**



*Dendrogram showing the distribution of classes of active forms of autonomous student characterizations in physics relative to each other*

Regarding disciplinary didactic autonomy, the analysis of the facets describing the autonomous student, along with their grouping into notional groups for each teacher, showed that all physics teachers highlighted notional groups related to the cognitive, psycho-affective, technical, and methodological domains of the AtA2d framework. The notional groups identified through this analysis are presented below, with emphasis on those that were common across teachers within each domain of autonomy.

Regarding the psycho-affective domain, all interviewees unanimously emphasized the importance of motivation in learning physics.

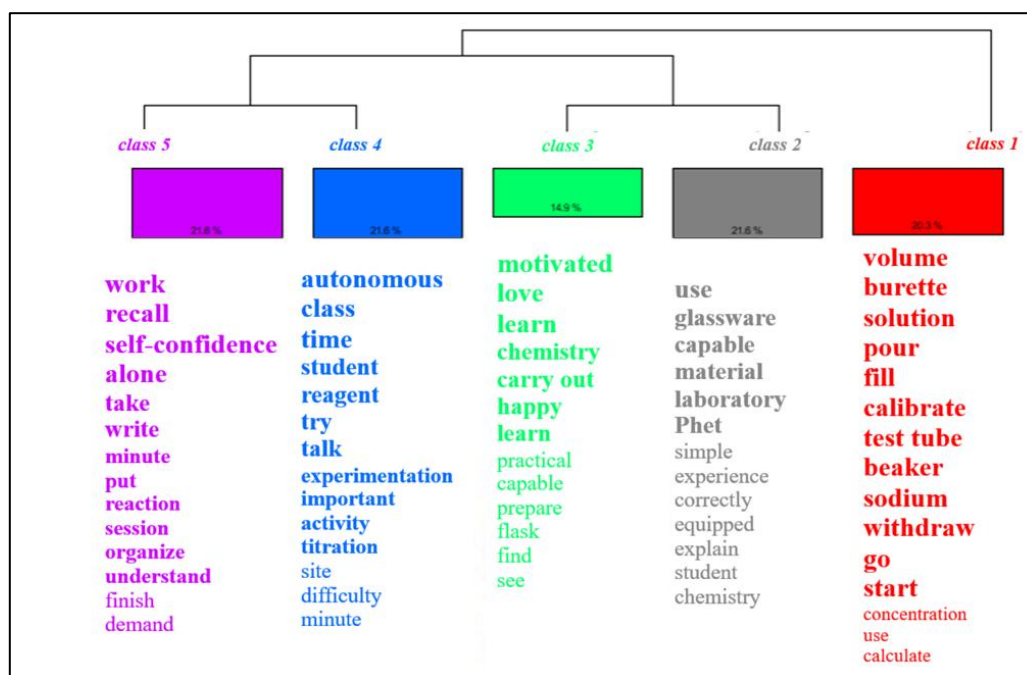
As for the technical, methodological, and cognitive domains, no single notional group was shared by all eight interviewees. However, several notional groups were mentioned by multiple teachers:

- Technical domain: three notional groups were commonly cited - (1) the use of mathematical techniques for vector plotting, (2) the mastery of measurement tools such as voltmeters and oscilloscopes, and (3) the use of digital simulations like those available on *phet.colorado*.
- Methodological domain: 2 recurring notional groups were identified - (1) the adoption of a systematic approach to solving mechanics problems and (2) the implementation of an experimental approach in mechanics.
- Cognitive domain: four notional groups emerged - (1) connecting real-world phenomena to theoretical models, (2) designing experimental protocols to demonstrate electromagnetic induction, (3) formulating hypotheses (e.g., to justify current flow without a generator or explain velocity exchanges during elastic collisions), and (4) performing mental operations related to momentum conservation in collision contexts.

We now examine the beliefs inferred from chemistry teachers' statements regarding the characteristics of autonomous students, through two complementary analyses: lexicometric analysis, using (DHC), and thematic analysis based on facets and the derived notional groups.

As shown in Figure 2, the (DHC) applied to the chemistry interviewees' responses groups the answers into five categories. The first concerns solution preparation; the second refers to basic experimental and digital skills; the third focuses on the development of positive attitudes toward learning chemistry; the fourth relates to time management during chemistry experiments; and the fifth involves working with confidence. Based on the content and dominant themes of each category, category 3 seems to be related to the psycho-affective domain. Categories 4 and 5 seem to be associated with the methodological domain, while categories 1 and 2 appear to correspond to the technical domain within the AtA2d framework. We now turn to the results of the thematic analysis.

FIGURE 2



*Dendrogram showing the distribution of classes of active forms of autonomous student characterizations in chemistry relative to each other*

Regarding transversal autonomy, the thematic analysis based on the facets and the notional groups derived from the interviews indicates that all 8 teachers emphasized aspects related to the technical domain. Grouping these facets revealed a common notional group across participants, specifically “mastering the technologies used, particularly software such as Microsoft Office”. According to all participants, an autonomous student exhibits strong proficiency in using these digital tools.

Regarding disciplinary didactic autonomy, the analysis of the facets and the notional groups describing the autonomous student, along with their grouping into notional groups for each teacher, showed that all chemistry teachers highlighted notional groups related to the psycho-affective, technical domains of the AtA2d framework

Regarding the psycho-affective domain, all interviewees unanimously emphasized the importance of motivation in learning chemistry.

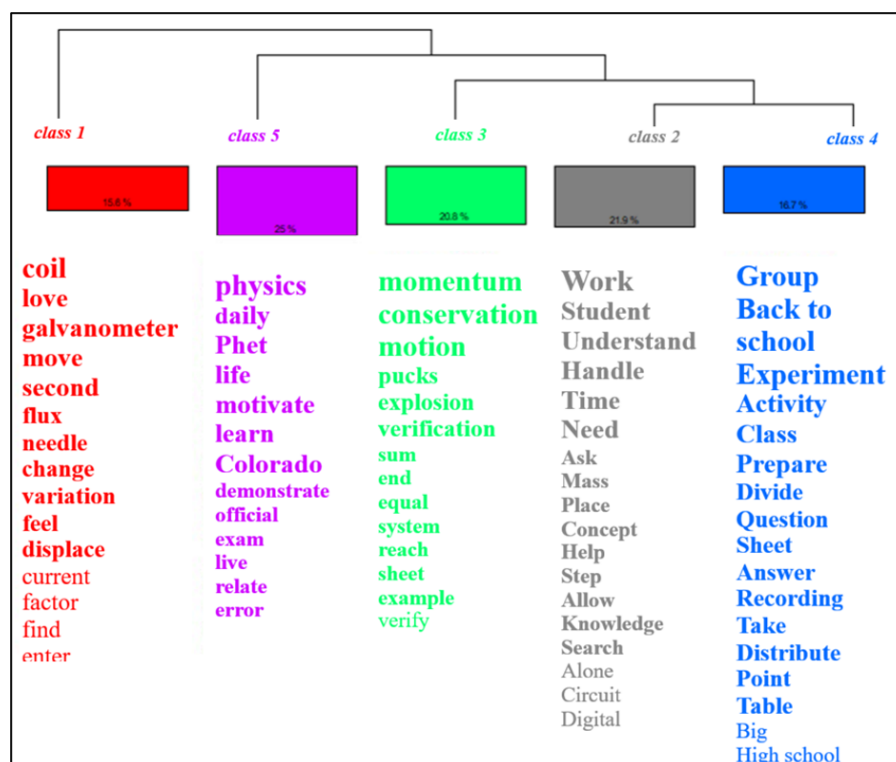
Regarding the technical domain, no single notional group was identified among all eight interviewees. However, four notional groups were shared by several of them. The first relates to experimental technique, particularly the use of laboratory glassware. The second concerns mathematical technique associated with graph plotting. The third refers to the preparation of

solutions by dilution. The fourth notional group focuses on the use of chemistry-specific simulations.

In summary, the interview results indicate that all 16 teachers associate transversal autonomy with students' ability to use digital tools such as Microsoft Office. The combined lexicometric (DHC) and thematic analyses provide complementary and convergent insights into teachers' about disciplinary didactic autonomy. For physics teachers, the lexical classes and notional groups identified correspond to the cognitive, technical, psycho-affective, and methodological domains of the AtA2d framework. For chemistry teachers, the results mainly relate to the technical and psycho-affective domains. Across both subjects, teachers consistently describe autonomous students as motivated learners who possess digital, experimental, and mathematical skills related to the discipline. Moreover, both analytical approaches point to the absence of informational and metacognitive domains: neither lexical classes nor notional groups were associated with these dimensions, and only one teacher referred to metacognitive aspects. This suggests that practices such as self-assessment or independent information seeking are rarely emphasized in the laboratory activities described. We now examine the beliefs inferred from physics teachers' and chemistry teachers' statements regarding how they report fostering student autonomy.

### *Beliefs of Physics and Chemistry teachers regarding student autonomy development*

**FIGURE 3**



*Figure 3 shows a dendrogram showing the distribution of classes of active forms characterizing the conditions that may support the development of autonomy in Physics relative to one another*

As shown in the figure 3, the classes identified by this DHC were characterized as follows: two of these classes focus on knowledge related to physics experiments (Classes 1 and 3); Class 2 relates to introducing students to hands-on manipulation; Class 4 concerns initiation into group

work during experimental activities; Class 5 relates to motivating students by making links with everyday experience and with the use of simulations such as PhET Colorado. In our view, these last three classes seem corresponding to conditions that may support respectively the methodological, psycho-affective, and technical domains of disciplinary didactic autonomy within the AtA2d framework in physics. We now turn to the results of the thematic analysis. The results of the thematic analysis showed that the development of strategies associated to transversal autonomy was linked to a limited number of notional groups, with no more than 3 teachers per domain. This is justifiable, as the teachers referred to learning sessions focused on specific disciplinary content.

Regarding disciplinary didactic autonomy, the analysis of the conditions describing the development of student's autonomy, along with their grouping into notional groups for each teacher, showed that physics teachers reported conditions they use that may foster the development of 3 domains of student's autonomy (technical, methodological, and psycho-affective), each associated with specific notional groups:

#### *Technical domain*

No single notional group was identified by all interviewees, yet two emerged among several teachers:

1. Mathematical prerequisites for experimental work, namely introducing students to the math behind plotting momentum vectors of two colliding carts. This group was cited by teachers who described the conservation-of-momentum experiment.<sup>2</sup>
2. Use of simulations (Phet, GeoGebra,), with all teachers providing students links to work on these tools. Notably, no notional group related to experimental technicality-as defined in our AtA2d physics reference framework-was mentioned.

#### *Methodological domain*

Two notional groups were common to all interviewees:

1. Scaffolding via resources (worksheets, equipment...).
  2. Provision of additional exercises aimed at official exam preparation
- Five further groups were mentioned by at least two teachers, including advance preparation of experimental activities (necessitated by the absence of a lab technician) and training students in time-management during experiments, as well as assessing their manipulative skills in the electromagnetic induction task.

#### *Psycho-affective domain*

A single notional group was shared unanimously: "Eliciting student interest and motivation by linking physics to everyday life." For every teacher, grounding lessons in real-world contexts served as the starting point for all classroom activities.

The classes identified by this DHC (figure 4) were characterized as follows: the first and fourth classes refer to "introducing students to laboratory manipulation"; the second is related to "dividing the class into groups during activities"; the third class "refers to introducing students to time management for the official exams"; the fifth relates to "linking learning to everyday experience". Considering the content and dominant themes of each category, these classes

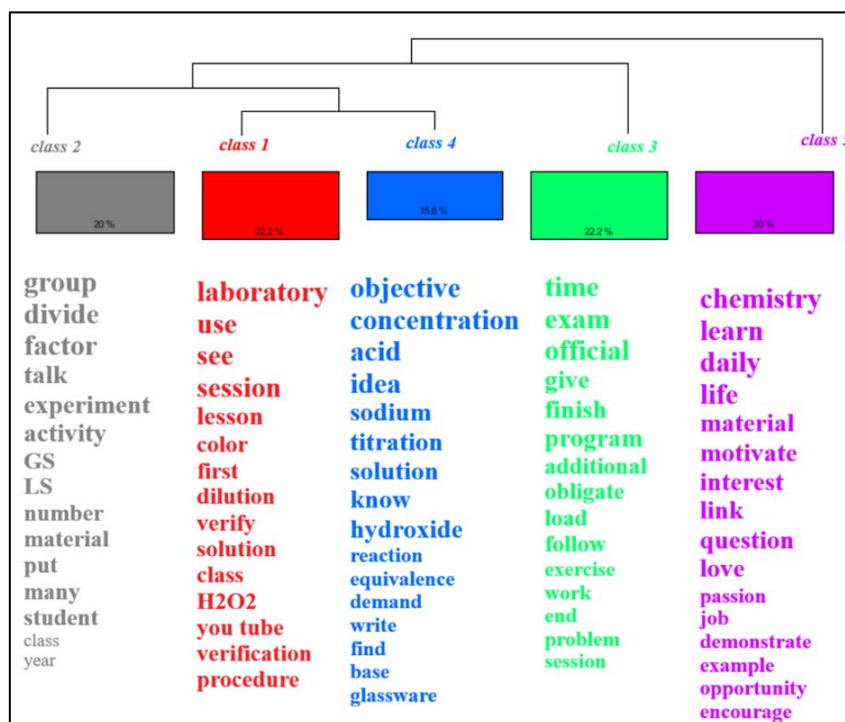
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<sup>2</sup> In our study, mathematical skills such as performing derivatives or plotting graphs are classified within the technical domain of the AtA2d framework rather than the conceptual domain because these skills represent tools already acquired by students in the third year of secondary school and are used as instruments to solve physics or chemistry problems. The focus is therefore not on evaluating students' autonomy in learning mathematics itself. In other words, for third-year secondary students, these basic mathematical competencies are considered technical **tools** applied in disciplinary contexts rather than conceptual reasoning in mathematics.

appear to correspond to the methodological, social, and psycho-affective domains of disciplinary didactic autonomy within the AtA2d framework in chemistry. We now turn to the results of the thematic analysis.

The thematic analysis results showed that strategies related to transversal autonomy were associated with a limited number of notional groups in chemistry, with no more than 2 teachers referring to them within each domain. This may be explained by the fact that the teachers described learning sessions focused on specific disciplinary content.

FIGURE 4



*Dendrogram showing the distribution of classes of active forms characterizing the conditions for the development of autonomy in chemistry relative to one another*

With regard to disciplinary didactic autonomy, the results showed that chemistry teachers' beliefs converged on conditions that support the development of the methodological and psycho-affective domains of autonomy, with consensus among all eight interviewees. The notional groups identified within these domains are summarized below.

#### *Methodological domain*

Four common notional groups were identified. The first, scaffolding through additional exercises, was cited by all the teachers, whereas the other three—the provision of essential resources for laboratory work, the preparation of materials for the experimental activity, and the evaluation of students' experimental performance—were mentioned by several teachers.

#### *Psycho-affective domain*

A single notional group was unanimously endorsed: "Eliciting students' interest and motivation for learning chemistry by linking the content to everyday life".

In summary, the interview results indicate that physics and chemistry teachers report similar conditions for fostering student autonomy during laboratory activities. The combined lexicometric (DHC) and thematic analyses offer complementary and convergent insights into these findings. For physics teachers, the lexical classes and notional groups identified correspond to the technical, psycho-affective, and methodological domains of the AtA2d framework. For chemistry teachers, the results mainly relate to the psycho-affective, and methodological domains. Across both subjects, the conditions reported by teachers emphasize methodological support for laboratory work as well as strategies aimed at sustaining students' interest and motivation. Moreover, both analytical approaches confirm the absence of informational and metacognitive domains, as neither lexical classes nor notional groups were associated with these dimensions. This suggests that practices such as information searching, reflection on learning, or self-assessment are rarely emphasized in the laboratory sessions described by the teachers.

## DISCUSSION AND CONCLUSION

This study, part of a doctoral dissertation, explores the beliefs inferred from interviews with Lebanese high school physics and chemistry teachers regarding the characterization of autonomous students and the strategies they report using to foster student autonomy. The research is based on a theoretical framework combining 2 components: teacher beliefs, the AtA2d framework in physics, and its adaptation to chemistry.

Teachers reflected on a previously taught lesson centered on a specific disciplinary concept in either physics or chemistry. The objective was to identify the domains of transversal and disciplinary didactic autonomy reflected in their statements, and to determine the conditions they consider essential for developing autonomy.

The results showed that, regarding transversal autonomy, all teachers emphasized students' mastery of digital tools such as Microsoft Office. In the context of disciplinary autonomy, teachers unanimously described autonomous students as motivated and as demonstrating digital, experimental, and mathematical skills aligned with the disciplinary content. Additionally, students in both subjects' approach practical work through an experimental activity.

Conversely, informational and metacognitive aspects were largely absent from teachers' responses, with only one interviewee referring to metacognitive elements. This suggests that self-assessment and research practices were either not observed or not prioritized in the learning activities described.

Both physics and chemistry teachers reported similar strategies for fostering student autonomy, such as motivating students by connecting the subject to everyday life, preparing them for official exams through additional exercises, and providing support through materials and laboratory resources. However, neither group addressed aspects related to the informational or metacognitive domains, possibly because these dimensions were not explicitly included in the lesson content or were not considered essential for promoting autonomy. Furthermore, the absence of lexical classes and notional groups derived from the teachers' interviews that relate to the development of the cognitive domain suggests that this dimension is not explicitly emphasized in the practices described by the teachers.

This research offers a significant contribution to science education by enhancing our understanding of how teachers would define autonomous student and how they think they develop it in physics classes or chemistry classes, fields where autonomy remains underexplored. On an international level, the study is original in its use of the AtA2d

framework, specifically designed for physics class, as opposed to the frequently used self-determination theory (e.g., El Bilani, 2007; Maddens et al., 2023; Makkonen et al., 2021).

Furthermore, defining autonomy through a set of indicators across seven domains allows for a more detailed analysis than previous models, as these indicators make it possible to infer whether a student can be considered autonomous.

For instance, Berger and Girardet (2016) identify only three types of conditions (organizational, procedural, and cognitive), while Furtak and Kunter (2012) focus on two categories—procedural and cognitive autonomy. These frameworks correspond only partially to the methodological and cognitive domains of the AtA2d model. Despite its valuable contributions, the study has several limitations. Theoretical limitations include the adaptation of the AtA2d framework to chemistry, which remains based on El Hage's model for physics (2023) and requires further empirical validation. Methodologically, the small sample size (8 physics teachers out of 403 and 8 chemistry teachers out of 369) limits the generalizability of the findings. While the data offer meaningful insights into declared practices, they must be interpreted with caution.

Another methodological limitation lies in the nature of teacher beliefs. As Pajares (1995) explained, beliefs can be inferred not only from teachers' statements but also from their classroom practices. Due to the COVID-19 pandemic and ongoing strikes in Lebanon since 2019, it was not possible to observe teachers in their classrooms. As a result, the study relies solely on teachers' verbal accounts, while acknowledging the potential gap between what is stated and what is practiced (Robert, 2012).

Despite these constraints, the study may serve as a springboard for future research. One promising avenue would be to compare the beliefs of French and Lebanese science teachers to explore the influence of institutional contexts on their definition of student autonomy.

## REFERENCES

- Albero, B. (2004). L'autoformation dans les dispositifs de formation ouverte et à distance : Instrumenter le développement de l'autonomie dans les apprentissages. In I. Saleh, D. Lepage, & S. Bouyahi (Éds), *Les TIC au cœur de l'enseignement supérieur : Actes de la journée d'étude du 12 novembre 2002* (pp. 139-159). Université Paris VIII-Vincennes-Saint-Denis, Laboratoire Paragraphe, coll. Actes Huit. [http://edutice.archives-ouvertes.fr/docs/00/00/17/75/PDF/Albero\\_Vincennes.pdf](http://edutice.archives-ouvertes.fr/docs/00/00/17/75/PDF/Albero_Vincennes.pdf).
- Barlet, R. (1999). L'espace épistémologique et didactique de la chimie. *BUP*, 93(817), 1423-1448.
- Bécu-Robinault, K. (2015). *Un cadre épistémo-sémiotique pour concevoir des séances et analyser des pratiques d'étude et d'enseignement de la physique*. Note de synthèse pour l'habilitation à diriger des recherches, Université de Toulouse Jean-Jaurès, France. <https://tel.archives-ouvertes.fr/tel-01237838/>.
- Berger, L., & Girardet, C. (2016). Les croyances des enseignants sur la gestion de la classe et la promotion de l'engagement des élèves : Articulations aux pratiques enseignantes et évolution par la formation pédagogique. *Revue Française de Pédagogie*, 196, 129-154. <https://doi.org/10.4000/rfp.5099>.
- Boilevin, J.-M., El Hage, S., Joffredo-Lebrun, S., & Gueudet, G. (2021). Développement de l'autonomie des élèves au collège. Points de vue d'enseignants de sciences physiques et de mathématiques. In M.-H. Hyndricks & C. Poffé, *Actes des 11èmes Rencontres scientifiques de l'ARDIST* (pp. 195-202), Bruxelles, Belgique.

Canac, S., & Kermen, I. (2016). Exploring the mastery of French students in using basic notions of the language of chemistry. *Chemistry Education Research and Practice*, 17, 452-473.

Ciekanski, M. (2019). Comment l'enseignant peut-il guider les élèves vers l'autonomie ? In Cnesco-IFÉ/ENS de Lyon, *De la découverte à l'appropriation des langues vivantes étrangères : comment l'école peut-elle mieux accompagner les élèves ?* Note des experts. [http://www.cnesco.fr/wpcontent/uploads/2019/04/CCLV\\_CIEKANSKI\\_MEF-v2.pdf](http://www.cnesco.fr/wpcontent/uploads/2019/04/CCLV_CIEKANSKI_MEF-v2.pdf).

Denouël, J. (2017). L'école, le numérique et l'autonomie des élèves. *Hermès, La Revue*, 78(2), 80-86.

Dethoor, A., Hainselin M., & Duclos, H. (2021). Vers une approche multidimensionnelle de l'autonomie. *Revue de Neuropsychologie*, 12(1), 29-33.

El Bilani, R., Montpied, P., & Le Maréchal, J.-F. (2007). Autonomie et motivation lors de l'apprentissage avec un simulateur. *Didaskalia*, 31, 1-32.

El Hage, S. (2023). Un cadre d'analyse didactique de l'autonomie des élèves et de son développement par les enseignants en classe de physique. *Note de synthèse en vue de l'habilitation à diriger des recherches*. Université de Reims Champagne-Ardenne, France. <https://hal.science/tel-04760319>.

El Hage, S. (2024). Vers un cadre d'analyse de l'autonomie des élèves en classe de physique. *Review of Science, Mathematics and ICT Education*, 18(1), 77-96. <https://doi.org/10.26220/rev.4662>.

El Hage, S., & Buty, C. (2014). La notion d'inscription appliquée aux pratiques enseignantes, une étude de cas en physique. *Recherches en Didactique des Sciences et des Technologies*, 10, 213-243.

El Hage, S., & Maigret, M. (2022). Autonomie en physique-chimie : Point de vue d'un représentant de l'institution. Un pas vers l'étude des éventuels décalages entre les attentes de l'institution et les pratiques enseignantes. *Bulletin de l'Union des Professeurs de Physique et de Chimie*, 116 (1041), 149-161.

El Hage, S., Boilevin, J.-M., & El Hajjar, D. (2021). Developing the students' autonomy in middle school: An exploratory study of French science teachers' points of view et the expectations of the school institution. *Review of Science, Mathematics and ICT Education*, 15(2), 77-99.

El Hajjar, D. (2025). *Autonomie des élèves en physique ou en chimie et son développement : croyances des enseignants libanais de terminale scientifique*. Doctoral dissertation, Université de Bretagne Occidentale, Brest, France. <https://tel.archives-ouvertes.fr/tel-05085625>.

El Hajjar, D., El Hage, S., & Boilevin, J.-M. (2021). Attentes des enseignants de la part d'un élève autonome en physique : Etude de cas au Liban. *Mediterranean Journal of Education*, 1(2), 106-118. <https://doi.org/10.26220/mje.3834>.

El Hajjar, D., El Hage, S., & Boilevin, J.-M. (2023). Autonomie des élèves en physique : Etude quantitative des points de vue des enseignants libanais. *Mediterranean Journal of Education*, 3(2), 36-45.

Flünger, B., Mayer, A., & Ümbach, N. (2019). Beneficial for some or for everyone? Exploring the effects of an autonomy-supportive intervention in the real-life classroom. *Journal of Educational Psychology*, 111, 210-234.

Furtak, E.-M., & Kunter, M. (2012). Effects of autonomy-supportive teaching on student learning and motivation. *The Journal of Experimental Education*, 80(3), 284-316.

- Gueudet, G., & Lebaud, M.-P. (2019). Développer l'autonomie des élèves en mathématiques grâce au numérique 1. Différentes dimensions de l'autonomie. *Petit x*, 109, 3-16.
- Guo, Y. (2019). Autonomisation des apprenants chinois de FLE : Analyse des interventions tutorales dans un dispositif de formation à distance. *Didactiques*, 8(1), 10-30.
- Halloun, I. (2004). *Inventories of basic dispositions: Synopsis*. [https://www.researchgate.net/publication/264942363\\_Inventories\\_of\\_Basic\\_Dispositions\\_Synopsis](https://www.researchgate.net/publication/264942363_Inventories_of_Basic_Dispositions_Synopsis).
- Jayawardena, P., Kraayenood, C., & Carroll, A. (2017). Promoting self-regulated learning in science: A case study of a Sri Lankan secondary school science teacher. *International Journal of Information and Education Technology*, 7(3), 195-198.
- Kermen, I. (2018). *Enseigner l'évolution des systèmes chimiques au lycée*. Presses Universitaires de Rennes, France.
- Le Bouil, A. (2022). *Effets d'un dispositif de formation d'enseignants : outils numériques pour développer l'autonomie des élèves en physique-chimie*. Thèse de doctorat, Université de Bretagne Occidentale, France. <https://hal.science/tel-04097772v1>.
- Le Bouil, A., El Hage, S., Jameau, A., & Boilevin, J.-M. (2019). L'autonomie des élèves dans l'apprentissage de la physique-chimie selon les enseignants. *Educational Journal of the University of Patras UNESCO Chair*, 6(1), 274-280.
- López-Belmonte, J., & Parra-González, M. E. (2022). Comparative analysis between a STEM-based learning process and traditional teaching. *South African Journal of Education*, 42, 1-10. <https://www.ajol.info/index.php/saje/article/view/249132>.
- Maddens, L., Depaepe, F., Raes, A., & Elen, J. (2023). Fostering students' motivation towards learning research skills: The role of autonomy, competence and relatedness support. *Instructional Science*, 51(1), 165-199. <https://doi.org/10.1007/s11251-022-09606-4>.
- Makkonen, T., Tirri, K., & Lavonen, J. (2021). Engagement in learning physics through project-based learning: A case study of gifted Finnish upper-secondary-level students. *Journal of Advanced Academics*, 32(4), 501-532. <https://doi.org/10.1177/1932202X211018644>.
- Minstrell, J. (1992). Facets of students' knowledge and relevant instruction. In R. Druitt, F. Goldberg & H. Medderer (Eds), *Research in physics learning: Theoretical issues and empirical studies* (pp. 110-128). Kiel: University of Kiel, Institute for Science Education.
- Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a Messy Construct. *Review of Educational Research*, 62 (3), 307-332.
- Patall, E. A., & Zambrano, J. (2019). Facilitating student outcomes by supporting autonomy: Implications for practice and policy. *Policy Insights from the Behavioral and Brain Sciences*, 6(2), 115-122. <https://doi.org/10.1177/2372732219862572>.
- Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., & Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *Journal of Educational Psychology*, 110, 269-288.
- Robert, A. (2012). A didactical framework for studying students' and teachers' activities when learning and teaching Mathematics. *International Journal of Technology in Mathematics Education*, 19(4), 153-158.

Robertson, L., & Gail Jones, M. (2013). Chinese and US middle-school science teachers' autonomy, motivation, and instructional practices. *International Journal of Science Education*, 35(9), 1454-1489.

Tiberghien, A. (1994). Modeling as a basis for analyzing teaching – learning situations. *Learning and Instruction*, 4, 71-87.

Tiberghien, A. (2012). Analyse d'une séance de physique en seconde : Quelle continuité dans les pratiques. *Education et Didactique*, 6(3), 97-123.