Inquiry-Based Science teaching & supporting students' autonomy: a case study in a French lower secondary

SUZANE EL HAGE

Université de Reims Champagne-Ardenne
France
suzane.elhage@univ-reims.fr

ABSTARCT

The aim of this qualitative case study is to analyse how a French science teacher's belief about student autonomy shape their teaching practices, particularly in the way they implement an Inquiry-Based Science Teaching (IBST) activity to foster students' autonomy. For this case study, we use the AtA2d framework distinguishes between two forms of autonomy, each with seven dimensions. We combine it with a communicative approach to analyse our data. The data include: a pre-teaching interview, a video recording of the lesson, and a post-teaching interview with a volunteer physic teacher. The results show that it is important to find an appropriate balance between "letting go" and fostering different dimensions of students' autonomy (Ad & At) during inquiry.

KEYWORDS

IBST, student Autonomy, mass and volume, French middle school

RÉSUMÉ

Cette étude de cas analyse les croyances d'un professeur de sciences exerçant en collège en France, notamment sa manière de définir un élève autonome. Elle étudie aussi sa façon de considérer l'investigation comme un moyen de développer cette autonomie, et la façon dont cela oriente ses pratiques. La recherche présentée s'intéresse plus précisément à une activité d'enseignement des sciences, centrée sur la mesure de la masse et du volume, menée par investigation pour développer l'autonomie des élèves. Nous utilisons le cadre d'analyse AtA2d, qui distingue deux formes d'autonomie, chacune comportant sept dimensions. Nous combinons ce cadre avec l'approche communicative pour analyser nos données (un entretien préalable, un enregistrement vidéo de la leçon et un entretien postérieur avec un professeur de physique bénévole). Les résultats montrent l'importance de trouver un juste équilibre entre le lâcher-prise et le développement des différentes dimensions de l'autonomie des élèves lors des investigations.

MOTS CLÉS

Investigation, autonomie des élèves, masse et volume, collège, France

INTRODUCTION

Inquiry-based Science teaching (IBST) is an important teaching strategy that can be implemented to achieve different learning goals: learning of science content or learning of inquiry skills and strategies (El Hage, 2021; Furtak et al., 2012; Furtak & Kunter, 2012; Minner et al., 2010; NRC, 1996). Like any other approach to teaching, the effectiveness increasing of student learning during implementing investigation activities is not per se effective. The result depends on several factors: how IBST is implemented (Boilevin, 2017); the teacher' guidance and interactions with students (Furtak & Kunter, 2012; Vorholzer & Aufschnaiter, 2019), the teacher belief about student autonomy and efficacity of investigation (Draganoudi et al., 2023) etc. Among these factors, we are particularly interested in the issue of student autonomy. This link between investigation and autonomy has been explored in several studies. Monod-Ansaldi et al. (2010) conducted a survey among 50 French teachers about investigations in science classes. Their study revealed difficulties in supporting independent work, linked to the teacher's pedagogical approach. Vince et al. (2013) show that French teachers find investigative approaches difficult to implement. They are time-consuming and require complex management of students who are often considered insufficiently autonomous. Vorholzer & Aufschnaiter (2019) illustrate that implementation with different types of guidance supports student engagement and promotes the development of student autonomy. Finally, Boilevin (2023) discusses the types of interactions and support that teachers should put in place to promote student autonomy in inquiry-based science learning. Within this perspective, the role of the teacher is crucial in this process. Teachers implement their investigations according to the objectives and recommendations specified in official curricula. What does the official French physics and chemistry curricula say?

Since 1999, middle school physics and chemistry curricula and official bulletins have recommended inquiry-based approaches and aimed to develop autonomy. Despite several reforms, autonomy remains a central objective (El Hage, 2024). It is often mentioned explicitly without being precisely defined to guide teachers. Each teacher interprets and implements it according to their own beliefs and practices. Thus, although both research and curricula emphasize the importance of inquiry and autonomy, their concrete application in the classroom remains unclear. The way the same resource is implemented may differ significantly depending on teachers' beliefs of autonomy and inquiry.

This study aims to analyse how a French science teacher's belief about student autonomy shape their teaching practices, more specifically to the different kinds of interactions through which they implement an IBST activity to foster students' autonomy.

THEORETICAL BACKGROUND AND RESEARCH QUESTIONS

The theoretical framework of this study is based on several key elements: teacher beliefs, student autonomy, classroom interactions, and the implementation of IBST. Student autonomy is specifically considered in the context of physics classes, and the framework for interactions focuses on science classroom interactions.

Teacher beliefs

All teachers have beliefs about their profession, themselves as professionals, and issues beyond their profession (Nguyen, 2014). There are a variety of definitions of the term "beliefs" as evidenced by Pajares' (1992) review of the literature on teachers' beliefs. He shows that beliefs influence how teachers view their role, make decisions in the classroom, and interact with their students. These beliefs affect many aspects of teaching: how students learn, which teaching strategies are considered effective, classroom management, motivation, etc. They are rooted in teachers' personal experiences, their training, the models they have observed, and their interactions with others. Vause (2009) follows in the footsteps of Pajares and defines beliefs as "implicit personal theories that can relate to three aspects: the student, the teacher, and the subject matter, as well as the relationships between these three aspects. These beliefs accumulate through teachers' personal and professional experiences and are generally resistant to change. They constitute a reservoir of values and prejudices that teachers draw on to act in situations and justify their actions" (p. 73). Teachers' beliefs directly influence their teaching practices (Farges, 2020; Pajares, 1992; Vause, 2009).

El Hajjar (2025) investigated high school physics teachers' beliefs about what it means for a student to be autonomous. This study, which was not related to IBST, shows that while some points of convergence can be observed in their beliefs, considerable divergences remain regarding the definition of autonomy. The same results were found for the middle school (El Hage et al., 2021; Le Bouil et al., 2019). These divergences in beliefs indicate that teachers' interpretations of autonomy may shape how they implement teaching approaches, including IBST. Therefore, beliefs impact the implementation of IBST, the development of student autonomy, and the ways in which teachers choose to interact -or not interact- with students at different moments during an activity, such as the resolution of an exercise or a laboratory task.

Inquiry based Science teaching

Inquiry-based learning or inquiry-based science teaching (IBL/IBST) can be defined in many ways (Suàrez et al., 2018). Definitions vary not only between the English-speaking and French-speaking worlds, but also within each of these contexts. El Hage & Ouvrier-Buffet (2018) note a clear distinction linked to historical and epistemological references: in France, reference is often made to Gaston Bachelard and the hypothetical-deductive method, while in the English-speaking world, the emphasis is on inquiry (Dewey, 1993).

To illustrate these two perspectives, we present a definition for each context. Pedaste et al. (2015), based on a meta-analysis of 32 articles, identify five key phases of inquiry-based learning:

- Orientation: fostering student curiosity ;
- Conceptualization: generating research questions and hypotheses;
- Investigation: allowing students to explore or experiment;
- Conclusion: enabling students to record findings and compare them with the tested hypotheses;
- Discussion: a transversal phase including communication and reflection.

It is possible to move back and forth between these phases, even though they are described here in a linear way.

In our French context, the definition of IBST follows Jean-Marie Boilevin (2023). He writes that "inquiry-based instruction can take many different forms and is, therefore, difficult to define" (p. 2). Instead of a single definition, he proposes a set of criteria that characterize inquiry-based learning in the physics classroom:

- Presence of scientific content ;
- Tasks or problems requiring cognitive and experimental activities;
- Argumentative discussions and peer communication ;
- Structuring of knowledge.

These two definitions, despite their different contexts, share key points. They emphasize active learning, experimentation, and the gradual construction of knowledge. In IBST, students research, experiment, interpret, and compare their ideas, which encourages their autonomy (Boilevin 2023; Monod-Ansaldi et al., 2010; Vorholzer & Aufschnaiter, 2019). But what is an autonomous student in a science class?

Student autonomy in Science classroom

The analytical framework Transversal Autonomy and Disciplinary Didactic Autonomy (AtA2d) developed by El Hage (2024) distinguishes between two forms of autonomy:

- Transversal autonomy (At) concerns elements of the student's work that are present in all disciplines. It does not depend on the nature of the knowledge involved in the classroom.
- Disciplinary didactic autonomy (Add or A2d) is linked to the knowledge involved. It is specific to the epistemological dimensions of the school subject (physics in our case) and is related to the particular tasks involved in teaching, studying, and learning the subject (physics). The modeling relationships that form the basis for the development of knowledge in physics, which are central to the teaching of this discipline (Tiberghien, 1994), on the one hand, and the semiotic aspect that enables the communication of knowledge in physics classes (Bécu-Robinault, 2018) on the other, are constitutive of this A2d framework.

At and Add are each divided into seven areas, as proposed by Albero (2004), and are constructed around a series of indicators. Those for AT are based on Albero's generic indicators (ibid.). Those for AD are also inspired by these indicators but are adapted to the nature of the knowledge and skills used in physics classes.

Table 1 presents indicators that characterize the dimensions of student autonomy when performing activities, with examples in physics to be specified according to the type of task.

TABLE 1

Summary of AtA2d. Different indicators of the dimensions of autonomy (At and Ad), with each Ad dimension illustrated by an example in physics

Dimensions of autonomy	Transversal autonomy (At)	Disciplinary didactic autonomy (Add)
Technical	Mastery of digital technologies used and ability to adapt to the diversity of tools and supports.	*Collecting information on measurable quanti *Mastery of digital tasks (using physics software/applications) or experimental equipm (measuring instruments, etc.). *Example:* the student is able to use a voltmeter and/or an ammeter independently in electricity to carry out a measurement.
Informational	Research and information processing: mastering documentary research tools, knowing how to search for and find information, etc.	*Searching and processing information on dedicated physics websites, in their notes, or in the textbook. *Identifying the nature of information. *Example:* The student distinguishes photos from drawings and diagrams of an electrical circuit following a documentary search.
Methodological	Organization of one's work in class or at home, taking into account objectives and various constraints.	*Implementing an experimental protocol provided by the teacher. *Proposing a protocol with clearly defined steps. *Example:* The student proposes a protocol to study the evolution of voltage as a capacitor charges over time (choice of equipment, setup – calibration – recording values – draw the graph).
Social	*Collaboration with peers and/or the teacher. *Developing an attitude of empathy, openness, and tolerance toward peers.	*Exchange and cooperation with other students about a physics situation. *Requesting help from the teacher appropriately in physics class.

		Example: In case of difficulty, the student asks the teacher for a "joker" during an investigation activity.
Cognitif	* Individual aspects of developing a work strategy. * Creating links between new elements and stabilized elements in mental representations.	*Establishing a connection between the world of objects/events and the world of theories/models. *Using a variety of mental operations related to physics content. *Example:d*uring an activity, the student connects the 'Sky Map' app display with the real sky.
Meta cognitif	Reflective activity on the action undertaken and on the efficiency of chosen learning strategies.	*Ability to self-assess and use mistakes to improve a strategy in physics. *Being aware of his/her own learning strategies in physics *Example:* In mechanics, the student knows the principle of inertia but is aware that they struggle to apply it to interpret simple movements in terms of forces.
Psycho-affectif	*Self-esteem: daring to answer when a question is posed to the whole class, daring to show one's work. *Motivation: extrinsic and/or intrinsic regarding content.	*Taking initiatives when solving an exercise or performing an experimental activity in physics. *Example:* The student is enthusiastic about conducting physics experiments.

The table provides a clear overview, but each dimension of autonomy should not be reduced to these indicators alone, which are only examples. The dimensions presented line by line, are not independent: there are dynamics between At and Add, without a single direction of influence being defined. In addition, interactions also occur between the different areas within each form of autonomy.

The value of the AtA2d analytical framework (El Hage 2024, 2025a) is that it highlights what is expected of an autonomous student in physics according to interconnected areas. This approach has also been used to study the perspectives of middle school teachers in France (El Hage et al., 2021), those of inspectors (El Hage & Maigret, 2022), as well as to analyse actual implementations (El Hage, 2025b; Morlet & El Hage, 2025).

Finally, let us recall the central role of the teacher in developing their students' autonomy (Ravestein, 1999). The teacher can select a resource before the session with or without digital tools (Gueudet & Loffredo-Lebrun, 2021). The potential of this resource and the freedom given to students to make decisions are important, but they are not enough. It is above all the teacher's attitude, decisions, and interactions with students during implementation that determine whether or not students' autonomy develops. These choices depend directly on the teacher's beliefs about what an autonomous student is and how to support them in becoming one.

Managing interactions in Science teaching

The communicative approach was developed by Mortimer and Scott (2003). This approach classifies the types of discourse between teachers and students in a science classroom according to two criteria: dialogic vs. authoritative and interactive vs. non-interactive.

- Communication is described as dialogic when the teacher takes into account the different points of view of the students. He or she acknowledges their ideas and discusses them.

- Communication is authoritative when the teacher accepts only one point of view, often that of academic knowledge. In this case, the teacher may rephrase the students' ideas or ignore them completely.
- Communication is considered as interactive when both the teacher and the students participate.
- Communication is described as non-interactive when it involves only the teacher or excludes the participation of others.

By combining these two criteria, we obtain four forms of discourse between the teacher and the students (dialogic/interactive; dialogic/non-interactive; authoritative/interactive; authoritative/non-interactive). Their articulation allows us to track the place of the students' and teacher's ideas over time. Indeed, Classroom discourse can be divided into episodes, each characterized as either interactive or non-interactive, and as either dialogic or authoritative. This typology is used to analyze the dynamics of communication in physics classrooms (Bécu-Robinault, 2018; Buty & Mortimer, 2008; El Hage & Buty, 2014; Morlet & El Hage, 2025 Scott et al., 2006).

We consider that the interactions observed in class are not neutral. They reflect the teacher's beliefs about student autonomy and how to support them in their learning.

Research question

In the French context, during practical physics classes, students generally work in pairs, particularly for experimental activities, planning protocols, or writing reports summarising in detail the experience. A teacher's beliefs about student autonomy and its development influence the types of interactions they establish during investigations. Our research questions are therefore as follows:

Q1: *What are a lower secondary physics teacher's expectation of an autonomous student* in the French context?

Q2: How do a lower secondary physics teacher's belief about student autonomy influence their interactions with students during IBST (Inquiry-Based Science Teaching)?

Q3: What balance does the teacher find between "letting go" and encouraging the development of different dimensions of student autonomy during IBST?

COLLECTING AND CODING DATA

Data gathering

Our exploratory study analyzes data collected from a volunteer teacher. This includes: a pre-session interview with the teacher, a classroom video, and a post-session interview conducted a few days after the video. In addition, we collected the worksheet that the students used to complete their work and which they had to fill out and hand in at the end of the session.

The chosen session was a lower secondary physics practical activity with a group of 16 sixth-grade students (5ème in the French system, around 11 years old). It focused on the determination of the mass and volume of both a solid and a liquid. The two objectives stated at the top of the student worksheet were: (1) to plan an experimental task, which requires drafting a protocol, and (2) to measure physical quantities directly and/or indirectly, which requires familiarization with laboratory equipment. More specifically, during this session, students have to work in groups had to answer the same question "*determine the mass and the volume*" for four different objects: water, a metal cylinder, a rubber stopper, and a screw).

The teacher presented the tasks with the cork stopper and the screw as *'surprise investigations'*, which, according to him, are designed to support his students' autonomy.

Coding process

The interviews (before and after the video session) and the classroom video were transcribed in full manually without the use of transcription software. The analysis was carried out in two stages:

First Stage

We began with two tasks.

- First, we analyzed the worksheet tasks to assess whether they involved an investigation and could support student autonomy.
- Second, we coded the pre-session interview to uncover the teacher's beliefs about student autonomy, using the AtA2d framework. This coding was done independently by two researchers. For example, the statement *"*The student must be able to complete a task without too much intervention or disruption from the teacher*"* was coded in the social dimension of transversal autonomy (Ast)**,** since it refers to managing interactions without any specific physics content.

Second stage

The second stage of coding was conducted at two levels.

- First level: we focused on the overall organization of the lesson. This allowed us to identify the dimensions of autonomy that were mobilized during its implementation. For example, when the teacher asked students to work in pairs and produce a common report on the requested measurements, we coded it as didactic social autonomy (Asd).
- Second level: we then analyzed the video of each pair during their workshop activity. Each workshop lasted about twelve minutes. We segmented the transcription of each workshop in episodes and coded it according to the communicative approach and the AtA2d framework. For instance, when the teacher told students what to do without giving them space to respond, we coded the episode *as* authoritative/non-interactive.

ANALYSIS OF THE TEACHING CONTEXT

A priori analysis of the resource in terms of investigation and student autonomy

According to the worksheet, students are expected to measure the mass and volume of four objects: water, a cork stopper, a screw, and a piece of metal. Each pair has 12 minutes per object, and all work on the four objects must be completed within a single 55-minute lab session.

For the screw and the cork stopper, some investigations are not explicitly written in the worksheet but emerge as students carry out the tasks:

- The screw: The balance cannot detect the mass of a single screw. Students use several screws, calculate the total mass, and then deduce the mass of one screw. The same issue occurs with volume: the displacement caused by a single screw is too small to measure accurately, so they must immerse multiple screws.
- The cork stopper: It floats. Students need to immerse it carefully to measure its volume without causing the water to overflow. The method must ensure that only the cork's volume is measured, excluding any fingers or tools used to submerge it.

Thus, for these two objects, it is clear that the tasks assigned to students go beyond simple technical measurements or the exercise of purely technical autonomy: they already incorporate elements of investigation. The resource includes several features that promote investigation, according to Boilevin (2023): students are required to engage with scientific content (determining the mass and volume of the objects, writing a protocol and a lab report) and carry out experimental activities to complete these tasks. The work is done in pairs, combining both experimentation and report writing. While not all the dimensions of investigation described by Boilevin (2023) are explicitly covered in the worksheet, it is likely that some emerge orally during the discussion of results and problematization. Finally, these "unexpected investigations" may foster the development of different dimensions of student autonomy (social didactic autonomy through pair work and collaborative report writing; cognitive didactic autonomy as students must figure out how to use multiple screws and perform the necessary calculations), although their actual impact strongly depends on how the teacher conducts the session.

Teacher's beliefs about student autonomy

Expressed in the pre-session interview

The analysis of the teacher interviews shows that, for him, autonomy is both transversal and didactic-disciplinary**.**

From a transversal perspective, an autonomous student is one who:

- Can complete a task without too much intervention or disruption from the teacher (Ast);
- Can organize their work to complete a task within the time allotted for the activity **(**Amt).

From a physics teaching perspective, an autonomous student is one who shows autonomy in relation to the tasks the teacher plans for the next day's lab:

- Knows how to use a balance and graduated cylinder to measure mass and volume **(**Atd**);**
- Can consult the method sheet provided in the notebook if needed (Aid**)**;
- Practices writing an experiment protocol alone during the holidays, as requested by the teacher (Amd);
- Independently writes clear and structured lab protocols during the session (Acd**)**;
- Can distinguish between an experimental protocol and a lab report (Acd);
- Knows how to interact with their lab partner to complete the assigned tasks in the worksheet (Asd**)**.

His beliefs about student autonomy shape his role in the lab, as he explains in the interview. He sees himself as a subtle facilitator, allowing students to experiment, make mistakes, and adjust their protocol without intervening unless asked: "Students need to understand that in science, I don't always have the correct answer on the first try. It's okay to start over and make mistakes"; "I want to let them be autonomous. I don't want to check on them or look at their worksheets…". When student are carrying out the tasks, he interacts as little as possible, enacting in practice the beliefs he expresses about fostering autonomy.

Observed and inferred from classroom practice (video-based)

The analysis presented here corresponds to the first level, focusing on the overall organization of the lesson to identify which dimensions of autonomy were mobilized. The lesson structure promotes transversal methodological autonomy (Amt), as students organize themselves to complete the tasks within the allotted time. The method sheet provided supports informational didactic autonomy (Aid), while working in pairs to handle the materials and produce a final document engages social didactic autonomy (Asd).

During the workshops, the teacher circulates between groups, responding to the requests of pair A and intervening spontaneously with pair B. All pairs clear their workstations on time, demonstrating real methodological autonomy. The video also shows that students complete the worksheet for each workshop just before leaving their place.

These observations align with the teacher's pre-session statements: he intended to let students experiment and make mistakes without intervening systematically, a stance confirmed by the limited interactions observed in the classroom. He believes that an autonomous student should be able to organize their work, collaborate effectively in pairs, and manage their time. Students indeed demonstrate these skills.

The teacher also expects students to seek information independently. The method sheet supports this belief and allows them to exercise this autonomy in practice. Finally, he wishes students to distinguish between protocol and report, but the written traces visible on the video suggest that this cognitive didactic autonomy (Acd) is not yet fully achieved, partly due to the nature of the teacher-student interactions.

Detailed analysis of student pair activities (video-based)

In this section, i present the analysis of only two pairs out of the eight observed during the lab session. These pairs were selected because they were the first to begin working with the objects that led to unexpected investigations

Pair A: Determining the mass and volume of a screw

This section presents a detailed analysis of the video of Pair A's activities, focusing on determining the mass and volume of a screw. For each quantity, we first describe the students' actions and then discuss the teacher-student interactions and their potential influence on the development of student autonomy.

<u>Mass measurement</u>

Pair A begins by attempting to measure the mass of a single screw, a challenging task because the balance cannot detect one screw. They must place several screws on the balance in order to obtain a readable measurement.

After five unsuccessful attempts (placing a single screw directly on the balance, using a small dish, handling it delicately, or less delicately) they call the teacher. Throughout this process, the students showed perseverance and displayed psycho-affective didactic autonomy (Apd) as well as social autonomy as they collaborate and support each other in overcoming the measurement difficulties.

➔ Teacher interactions and its impact on autonomy development

The teacher interacts with the students only after they raise their hands. He provides guidance through non-verbal cues, manipulating the pile of screws and asking direct questions about similar tasks: "10 candies weigh 40 g; what is the mass of a single candy?" The students answer 4 g. Seeing no initiative from them, he places 10 screws on the balance, which reads 40 g, and then steps back, asking the students to perform the calculation. The students then perform the calculation to find the mass of a single screw, without taking any initiative. This authoritative interaction limits their cognitive autonomy (they follow the procedure without constructing knowledge) and metacognitive autonomy (they do not reflect on mistakes or fully exploit the result). It also reduces their engagement in the investigation, as they are not cognitively involved to find solutions on their own.

The interactions between the teacher and the students show that the opportunities to develop certain dimensions of autonomy during this IBST session are limited due to infrequent and highly authoritative interactions:

- Students were not given the opportunity to find the solution on their own, restricting their cognitive autonomy.

- They cannot think about the weighing strategy or adjust their procedure, which limits their metacognitive autonomy.
- Their role was limited to following the teacher's instructions, even though they performed the final calculation themselves.

Volume measurement

To determine the volume of a screw, Pair A begins by filling the graduated cylinder with water. When they immerse a single screw, the water level barely changes and does not rise in a clear, readable way. They then try adding 40 mL of water, but the measurement remains unreadable. After five unsuccessful attempts, they call the teacher for assistance.

Throughout this process, the students demonstrate perseverance and display psycho-affective didactic autonomy (Apd) as well as social autonomy. In addition, the pair shows methodological autonomy, effectively managing their time and clearing their workstation.

➔ **Teacher interactions and impact on autonomy development**

The teacher arrives, listens to the students' question, and immediately suggests a strategy: immerse several screws so that the volume can be measured. The students follow the teacher's instructions, read the value on the graduated cylinder, perform the calculation, and then complete the three sections of the worksheet: materials used, protocol, and lab report.

This authoritative interaction shows that the teacher's limited and directive approach restricts students' opportunities to develop autonomy and engage fully in the investigation:

- The students did not find the solution themselves; the teacher directly guided their actions, limiting their cognitive autonomy.
- They could not test or adjust different strategies on their own because the interaction was authoritative and non-interactive, which hindered their metacognitive autonomy.
- Their role was reduced to following the teacher's instructions to obtain a correct measurement, limiting their active engagement in the investigative process.

Looking at the activities carried out by Pair A, both for measuring mass and volume, it becomes clear that while students develop technical autonomy through repeated handling of the balance and graduated cylinder, the teacher's authoritative interactions during critical steps restrict their cognitive and metacognitive autonomy and limit active engagement in the investigation. This highlights the tension in inquiry-based teaching. Students need space to explore on their own, but the teacher intervenes in an authoritative way only when they ask for help. This raises a practical question for inquiry-based teaching: how long should students be left to work independently, and should the teacher wait for them to ask for help or step in sooner to move on to the next step?

Pair B: Determining the mass and volume of a cork

For this workshop, finding the mass was simple. The pair used a balance, tared it, and weighed the cork. The task was done, and the balance put aside in less than two minutes. For the volume, when the students placed the cork in the graduated cylinder filled with water, they saw that it floated. They had to find a way to push it under the water to measure the volume. The teacher had provided a small piece of metal for this purpose. With it, the cork could sink, a reading could be taken from the cylinder, a subtraction made (actually, two subtractions are needed, since the increase in water level corresponds to the volume of both the cork and the metal), and the cork's volume found without including the metal. Pair B completed both the mass and volume measurements and put away the equipment on the bench within 10 minutes, showing transversal methodological autonomy (Amt).

It should be noted that the teacher walked past this pair and saw that they had finished in less than ten minutes. He came closer and asked them directly: "How did you manage with the cork?". A student of Pair B explained that they had pushed it down with a pen, and that the cork had not floated back up. The other student nodded to confirm. The teacher said, "He said okay while nodding his head in a way that suggested he wasn't completely in agreement" and walked away. He accepted the students' method without questioning it, even though it introduced a scientific error. He walked away without looking at what they had written in their notebook. The mass and volume values they recorded did not have the correct units.

These students had found their own solution to the problem: "make the cork sink". They did not use the tool the teacher had prepared, but it worked. This shows a development of their methodological autonomy. They are also beginning to develop cognitive autonomy, as they recorded the values but did not use the correct units, which still needs support. Through repeated handling of the balance and graduated cylinder, the students develop technical autonomy. Apart from this brief, teacher short interaction, authoritative-interactive, there were no other interactions between the students and their teacher

In our case, there were about two minutes left. The method the students found was not correct, but they finished early, so the teacher came over. We can wonder: if they hadn't finished on time, would the teacher have come to check on them, since the students didn't call him. It seems that in their beliefs about autonomy, being autonomous means working alone and it's up to the student to call the teacher. It seems his main concern was that the surprise investigation didn't disturb the students: they noticed the problem, figured out what to do, and that was it. Despite the investigative situation offered to the students, the events that took place highlights a tension: expecting students to work entirely on their own and call the teacher only if needed can hinder the development of several dimensions of autonomy. They were not truly autonomous—methodologically, didactically, or cognitively. Overall, limited teacher interaction in a task that leaves students to act alone can slow the growth of these dimensions without guidance.

CONCLUSIONS AND DISCUSSIONS

This qualitative study aims to explore the relationship between the development of student autonomy in laboratory work and the amount of student-teacher interactions during IBST. It takes place in a French context where students (11 years) are asked to design an experimental protocol and carry out investigations to determine the mass and volume of objects.

Regarding the first research question, the teacher's beliefs reflect both transversal and didactic-disciplinary expectations: students should be able to manage their work independently, organizing tasks and completing them on time, which reflects social and methodological dimensions of transversal autonomy. He also believes that students, working in pairs, should handle lab equipment correctly, consult method sheets when needed, write clear and structured protocols, distinguish between protocols and reports, and collaborate effectively with their partners, reflecting many dimensions didactic-disciplinary autonomy. To allow students to develop this autonomy, he gives students a relatively IBST activity that requires them to think for themselves, while deliberately keeping his own interventions to a minimum, stepping in only when students ask for help.

Regarding our second and third research questions, the teacher's beliefs about student autonomy shape his interactions in the lab: he gives students relatively open IBST tasks that require them to think independently and work in pairs. For pair A, he intervened only when the students explicitly asked for help, providing authoritative interactions; the students mostly executed instructions, which limited the development of cognitive autonomy (Acd). For pair B, he approached spontaneously, asked a question, but did not give indicators. In both cases, the surprise investigations aimed to foster cognitive autonomy. The limited interactions, especially when the teacher only intervenes at the students' request, can slow/stop the development of some dimensions of the didactic autonomy.

Letting students organize themselves freely to find the mass and volume of objects and barely interacting to remind them about writing a protocol and a report, can reduce the meaning of the experiment. Students may miss the link between planning, doing, and reporting, which makes the experiment less useful for learning.

This study shows how a teacher's beliefs shape his interactions with students and the development of autonomy during IBST. It also highlights the importance of balancing letting students work on their own (letting go) with knowing when and how to interact to support both transversal and didactic-disciplinary autonomy.

In this text, we do not analyze students' written productions, but they should be considered in future work as a perspective to further understand the development of autonomy in inquiry-based activities.

REFERENCES

Albero, B. (2004). L'autoformation dans les dispositifs de formation ouverte et à distance : instrumenter le développement de l'autonomie dans les apprentissages. Dans I. Saleh, D. Lepage & S. Bouyahi (Dirs), *Les TIC au cœur de l'enseignement supérieur*. *Actes de la journée d'étude du 12 novembre 2002* (pp. 139-159). Publication de l'université Paris VIII-Vincennes-St Denis, France.

Bécu-Robinault, K. (2018). *Analyse des interactions en classe de physique : Le geste, la parole et l'écrit*. L'Harmattan.

Boilevin, J.-M. (2017). La démarche d'investigation : Simple effet de mode ou bien nouveau mode d'enseignement des sciences. Dans M. Bächtold, V. Durrand Guerrier & V. Munier (Dirs), *Épistémologie et Didactique*, (pp. 195-220). Presses Universitaires de Franche-Comté.

Boilevin, J.-M. (2023). Inquiry-based science education: Between teacher guidance and student autonomy in learning physics. In *AIP Conference Proceedings*, 2595(1), 040004. https://doi.org/10.1063/5.0123773.

Buty, C., & Mortimer, E. (2008). Dialogic/authoritative discourse and modelling in a high school teaching sequence on optics. *International Journal of Science Education*, *30*(12), 1635-1660. https://doi.org/10.1080/09500690701466280.

Dewey, J. (1993). *Logique : La théorie de l'enquête*. Paris: Presses Universitaires de France.

Draganoudi, A., Lavidas, K., Kaliampos, G., & Ravanis, K. (2023). Developing a research instrument to record preschool teachers' beliefs about teaching practices in Natural Sciences. *South African Journal of Education, 43*(1), 2031. https://doi.org/10.15700/saje.v43n1a2031.

El Hage, S. (2021). Physicists research practices: A perspective to rethink inquiry-based science education. *Al-Biruni Journal of Physics Education*, *10*(02), 86-97. https://doi.org/10.24042/jipfalbiruni.v10i2.8697.

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. (2025a). Un cadre d'analyse didactique de l'autonomie des élèves et de son développement par les enseignants en classe de physique. *Recherches en Éducation*, *57*, 153-171. https://doi.org/10.4000/131p0.

El Hage, S. (2025b). Forme de discours en classe de physique et développement de l'autonomie des élèves : Étude de cas en cinquième. In V. Munier & M. Bächtold (Éds), *Actes des XIIIe Rencontres scientifiques de l'ARDIST* (pp. 547-556). Éditions de l'ARDIST.

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 & the expectations of the school institution. *Review of Science, Mathematics and ICT Education*, *15*(2), 77-99. https://doi.org/10.26220/rev.3826.

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. https://doi.org/10.4000/rdst.960.

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., & Ouvrier-Buffet, C. (2018). Les démarches de chercheurs en physique et en mathématiques. Enjeux didactiques d'une nouvelle approche épistémologique. *Recherches en Éducation*, *34*, 62-82. https://doi.org/10.4000/ree.1932.

El Hajjar, D. (2025). *Autonomie des élèves en physique ou en chimie et son développement : croyances des enseignants libanais de terminale scientifique*. Thèse de doctorat, Université de Rennes, France. https://theses.hal.science/tel-05085625.

Farges, G. (2020). Croyances et pratiques des enseignants, entre acceptation des consignes et expertise professionnelle. Introduction. *Revue Internationale d'Éducation de Sèvres*, *84*, 53-61. https://doi.org/10.4000/ries.9533.

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. https://doi.org/10.1080/00220973.2011.573019.

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of Educational Research*, *82*(3), 300-329. https://doi.org/10.3102/0034654312457206.

Gueudet, G., & Joffredo-Lebrun, S. (2021). Teacher education, students' autonomy and digital technologies: A case study about programming with Scratch. *Review of Science, Mathematics and ICT Education*, *15*(1), 5-24. https://doi.org/10.26220/rev.3575.

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. https://hal.science/hal-02535355/.

Minner, D.-D., Levy, A.-J., & Century, J. (2010). Inquiry-based science instruction-what is it and does it matter?: Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496. https://doi.org/10.1002/tea.20347.

Monod-Ansaldi, R., Digard, I., Florimond, A., Fontanieu, V., Péres, C., Rossetto, A. -M., & Morel-Deville, F. (2010). L'investigation en MI-SVT : Un chemin vers l'autonomie des élèves ? Dans *Actes des journées scientifiques DIES* (pp. 87-97). INRP.

Morlet, C., & El Hage, S. (2025). Tensions entre interactions didactiques et rôle des écrits des élèves dans le développement de l'autonomie : Étude de cas en classe de cinquième en physique-chimie. *Mediterranean Journal of Education*, *5*(2), 71-90. https://ejupunescochair.library.upatras.gr/mje/article/view/5422.

Mortimer, E.-F., & Scott, P. (2003). *Meaning making in secondary Science classrooms*. McGraw-Hill Education.

Nguyen, T. N. (2014). *Learner autonomy in language learning: Teachers' beliefs*. PhD thesis, Queensland University of Technology, Australia. https://eprints.qut.edu.au/69937/.

NRC (National Research Council). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Pajares, F. (1992). Teachers’ beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307-332. http://www.jstor.org/stable/1170741.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003.

Ravestein, J. (1999). *Autonomie de l’élève et régulation du système didactique*. De Boeck.

Scott, P., Mortimer, E.-F., & Aguiar, O.-G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education*, *90*, 605-631. https://doi.org/10.1002/sce.20131.

Suárez, Á., Specht, M., Prinsen, F., Kalz, M., & Ternier, S. (2018). A review of the types of mobile activities in mobile inquiry-based learning. *Computers & Education*, *118*, 38-55. https://doi.org/10.1016/j.compedu.2017.11.004.

Tiberghien, A. (1994). Modeling as a basis for analyzing teaching – learning situations. *Learning and Instruction*, *4*, 71-87. https://doi.org/10.1016/0959-4752(94)90019-1.

Vause, A. (2009). Les croyances et connaissances des enseignants à propos de l’acte d’enseigner. Vers un cadre d’analyse. *Les Cahiers de Recherche en Éducation et en Formation*, *66*, 4-28.

Vince, J., Monod-Ansaldi, R., Prieur, M., & Fontanieu, V. (2013). *Représentation sur la discipline, son apprentissage, les démarches d'investigation et quelques concepts-clés : Quelles spécificités pour les enseignants de Sciences Physiques ?* https://shs.hal.science/hal-01017802v1.

Vorholzer, A., & Aufschnaiter, C.-V. (2019). Guidance in inquiry-based instruction - an attempt to disentangle a manifold construct. *International Journal of Science Education*, *41*(11), 1562-1577. https://doi.org/10.1080/09500693.2019.1616124.