A Model-Based Inquiry Sequence as a Heuristic to Evaluate Students’ Emotional, Behavioural, and Cognitive Engagement

M. Rut Jimenez-Liso1 · Alberto Bellocchi2 · Maria Martinez-Chico1 · Rafael Lopez-Gay1

Accepted: 19 May 2021 / Published online: 19 June 2021
© The Author(s), under exclusive licence to Springer Nature B.V. 2021

Abstract
In this study we address the need to promote student engagement with school science and the need to measure a more comprehensive conception of engagement considering three dimensions of engagement: emotional, behavioural, and cognitive. We address the first issue by designing and implementing a model-based inquiry instructional sequence focused on fostering students’ engagement with science. The second issue is addressed by developing and testing a heuristic that measures student engagement holistically by focusing on all three dimensions mentioned. The results report that our short MBI instructional sequence develop students’ emotional engagement because most of them recognize to having felt interest, concentration, and satisfaction and few students reported boredom, shame, or rejection during the teaching. They spent most of the time working in small groups and sharing-discussing their hypothesis, planning and evaluating their experimental designs, and building models to explain acid-base phenomena together which highlight behavioural and cognitive dimension of students’ engagement in our instructional sequence about chewing gum and pH of the mouth. The heuristic is designed to gather data continuously during instruction with minimal disruption to the learning and teaching sequence. The heuristic can be used by teachers, researchers, and also by students, to gain multi-level understandings about engagement by focusing on individual, group-level, or class-level analysis of responses.

Keywords Students’ engagement · Emotions · Behavioural · Cognitive · Model-based inquiry · Heuristic for evaluation

M. Rut Jimenez-Liso
mrjimene@ual.es

1 Sensociencia Team, CEIMAR-University of Almeria, Almeria, Spain
2 School of Teacher Education and Leadership | Faculty of Creative Industries, Education, and Social Justice, Queensland University of Technology, Brisbane, Australia
Introduction

Positive feelings and interest towards school science manifested by students in the early years of schooling can quickly erode into disinterest, disengagement, and boredom as they advance to middle and high school (Lyons & Quinn, 2010; Murphy & Begg, 2003). The high levels of student disengagement observed in other countries echo conclusions of an extensive study that shows Spanish school students’ interest in science, and the image they have of scientists continues to be low despite marginal improvements in recent years (FECYT, 2019). Disengagement with school science has been attributed to the fact that school science gains a growing negative image as being authoritarian, boring, difficult, useless, and the cause of environmental problems in students’ minds (Vázquez & Manassero, 2008). The Spaniard school, where this study takes place, reflects the same levels of disengagement noted above, making it an ideal location in which we explore the effectiveness of an intervention designed to improve students’ science engagement.

As Olitsky and Milne (2012) mention, for some teachers, engagement is sometimes conceptualized as an individual construct, and from such a perspective, when one is disengaged, the responsibility for becoming engaged rests with the individual student. On other occasions, teachers describe how they do not sufficiently engage their students, which then places the focus and the responsibility on the individual teacher (Olitsky & Milne, 2012). From our view, for a better understanding of engagement in science learning, a greater number of studies need to attend to collective rather than individual engagement. Moreover, past research has addressed cognitive and behavioural engagement with less attention being given to emotional engagement with science.

Science educators, researchers, and curriculum developers encourage us to implement scientific practices to motivate students, to turn them into active learners, and to enhance student engagement with science (Osborne & Dillon, 2008). Inkinen et al. (2020) point out research about engagement also should work on identifying which activities promote engagement the most. Two science teaching practices that have been recommended for their capacity to engage students with school science include inquiry and modelling practices (Grabau & Ma, 2017; Milne & Otieno, 2007). These recommendations present teachers with what their teaching could be like, and they do not explain what teachers should look for to evaluate their students’ engagement.

Before proposing a systematic assessment of student engagement, it is necessary to clarify the meaning of engagement as used in this study. Briefly, we understand student engagement through a multidimensional model that includes behavioural, emotional, and cognitive engagement (Antúnez et al., 2017; Fredricks et al., 2016; Olitsky & Milne, 2012). One limitation to past research is the overemphasis on cognitive or behavioural engagement to the exclusion of emotional engagement, an ever-growing area of contemporary science education research (Bellacchi et al., 2017; Olitsky & Milne, 2012). It is thereby necessary to understand student engagement with school science more comprehensively by including measures of students’ emotional engagement alongside measures of cognitive and behavioural engagement. In this study we address two issues: (1) the need to promote student engagement with school science and (2) the need to measure a more comprehensive conception of engagement considering all three dimensions of engagement. We address the first issue by designing and implementing a model-based inquiry (Windschitl et al., 2008) instructional sequence focused on fostering students’ engagement with science. The second issue is addressed by developing and testing a heuristic that measures student engagement holistically by focusing on emotional, behavioural, and cognitive dimensions.
Although instruments for measuring engagement in research are readily available, typically these are designed to be administered at the end of instruction (e.g. Riffert et al., 2020). A limitation of such approaches for informing teaching and learning is that they may capture only those events that are proximal to the time of administering the instrument. Although there are some studies that address the effect of inquiry-based approaches on science students’ engagement and understanding (Arthur, 2005; Nasution, 2018; Smallhorn et al., 2015), those that focus on a combination of students’ cognitive and emotional self-reflection when experiencing inquiry-based instruction are scarce. More specifically, it is hard to find heuristics designed for students to self-evaluate their engagement, with the specific inclusion of emotional engagement. One of the main contributions of our study is the development and evaluation of a heuristic designed that includes emotional, cognitive, and behavioural dimensions of engagement. Our heuristic is designed in such a way that it not only provides research evidence of all three dimensions of engagement, but it also contributes to teaching and learning processes.

**Theoretical and Empirical Underpinnings**

**Model-Based Inquiry**

There are numerous studies that demonstrate how the implementation of scientific (inquiry) practices and modelling promotes student’s engagement with school science (Bevins & Price, 2016; Crujeiras-Pérez & Jimenez-Aleixandre, 2017). Scientific practices include the following processes: construction, use, and evaluation of models (modelling); expression and discussion of ideas; searching for evidence to contrast ideas (inquiry), whereby statements are evaluated based on evidence; and recognizing that scientific conclusions and statements must be justified (argumentation) (Jiménez-Liso et al., 2020b; Osborne, 2014). In this study, we adopt the model-based inquiry (MBI) instructional approach as a set of practices that are closely related to scientific activity and reasoning (Windschitl et al., 2008). In emphasizing MBI, we envision that it might support students developing an understanding of the disciplinary core ideas, to also develop procedural and epistemic practices (Osborne, 2014). In this article, we only focus on assessing ideas and experimental designs proposed by students. Epistemic understandings must be evaluated through implementing instructional sequences with explicit and implicit approaches of nature of science (Duschl & Grandy, 2008; Jiménez-Liso et al., 2020a).

The goal of MBI is to develop defensible explanations of the way the natural world works (Windschitl et al., 2008; Jiménez-Liso et al., 2021). Specifically, our interpretation of MBI is based upon generating, testing, and revising scientific models, being primarily centred round the collaborative styles of learning that inquiry and so the evidence-based knowledge imply, also placing particular emphasis upon the explanatory model (Nuffield Foundation, 2013). In the pursuit of deepening students’ understanding by using logic and evidence about the natural world, Crawford (2014) proposed students will participate on addressing questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models, and communicating findings. Thus, these actions can be transforming into tasks of an MBI instructional sequence as Jiménez-Liso et al., (2020a) have developed, and some of them could be part of the heuristic to evaluate the students’ engagement.

**Learning-Related Multidimensional Engagement**

Various definitions recognize multiple and interrelated dimensions of student engagement with school including cognitive, behavioural, affective-emotional, academic, or social engagement (Antúnez et al.,
2017; Fredricks et al., 2016). Some of these engagement dimensions refer to whether students go to school, perform homework punctually, participate in school democratic organization, etc. The conceptualization of engagement we adopt addresses the need for holistic understanding that moves beyond focusing on cognitive and behavioural engagement alone (Fredricks et al., 2016; Olitsky & Milne, 2012). With the aim of providing teachers with a systematic assessment of their students’ science engagement, in this paper we will focus on three dimensions that directly concern class tasks: emotional, behavioural, and cognitive dimensions of engagement.

Despite the high emotional charge teaching usually has, science teachers often ignore the emotional aspects of learning (Jeong et al., 2016). Reeve (2013) points as emotional engagement indicator the presence of emotions facilitating the task (enthusiasm, curiosity, interest...) or absence of emotions hindering the task (fear, frustration, anxiety, rage...). Following Olitsky and Milne (2012), attitudes and emotions can facilitate active learning in students or limit the capability of students to learn, leading to demotivation and disinterest. Inkinen et al. (2020) identify which tasks in an instructional sequence promote better situational engagement, i.e. the impact of instructional sequence has on students’ interest. The relationship between learning and emotions were called learning-related emotions by Wittmann (2011).

The behavioural dimension of engagement refers to all those behaviours carried out by students based on their interest in learning and achieving academic performance, their active or passive participation in activities developed in the classroom or out-of-school, focusing on in their efforts and their attention to tasks performed, among others (Antúnez et al., 2017).

The cognitive dimension of engagement refers to all the thoughts, beliefs, and perceptions that learners have regarding the importance of academic work and the subsequent effort, as well as the cognitive and metacognitive strategies that students must develop in order to build significant learning processes (Antúnez et al., 2017). Fredricks et al. (2016) add reflection, willingness to make an effort, and self-regulation of learning to the cognitive engagement dimension.

In the same way as the emotional dimension of engagement, we want to our students to be aware of what they learn when developing the MBI instructional sequence, task by task, because we want to analyse the correlation between their self-regulation of learning and their emotions self-report.

Study Context and Design

The Science Education Context in Spain

This study takes place in two Spanish southeast secondary school science classrooms. The school is located in a rural town with a population of approximately 88,000 people of whom 33% are not born in Spain. Intensive farming is the main industry. The school, with students from 12 to 18 years of age, has a remarkably prominent level of absenteeism, because, in many cases, parents often require students to help with agricultural work. In addition, a high student to teacher ratio of 30:1 is common. There is a high degree of racial, ethnic, and religious diversity, and not all students at the school are able to communicate in Spanish; for most, Spanish is a second language.

In the two classrooms involved in this study, 15 students (36%) belong to second-generation immigrant families, with parents originating in the north of Morocco (6), sub-Saharan (5), and Romania (4). The teachers of both classes report difficulties in managing classroom behaviour and express concerns over students damaging scientific equipment or causing and sustaining injuries. These anxieties fuel an avoidance of practical work in science.
In relation to the scientific content of this paper, acids and bases are a topic rarely taught at primary or secondary school levels. In the Spanish primary and secondary school curricula, chemical reactions are only exemplified through oxidations, combustions, and fermentations, with no mention of acid-base reactions. In the Spanish curriculum, acid-base content such as acid-based models (Arrhenius, Brønsted-Lowry and Lewis), equilibria, or regulation reactions is not found in curriculum and instruction for students in the age group of our study participants.

**Motivation for Our Study**

In the absence of science inquiry and laboratory activities in classrooms in Spain, such as those at the centre of this study, school students typically experience science learning through pen and paper algorithms, repetitive exercises, and memorization of science content delivered through teacher-centred instruction (Mostafa et al., 2018). As the PISA 2018 results show, 37% of Spanish secondary school principals reported that student learning is hindered to some extent or a lot due to school staff resisting curriculum change (page 112). Fifteen-year-old Spanish students asked by the PISA (OECD, 2019) admit to participating in scientific activities less than the average of both OECD countries or other EU students with greatest significant differences between the extreme proficiency groups: in both variables “scientific activities” and “teacher-directed science teaching”, students with a low level of proficiency in science have values for these indices that are below the international mean (negative values) vs those with a high level of proficiency display values close to the international mean (Tourón et al., 2018).

This context prompted Authors 1 and 4 to deliver professional development on science inquiry for in-service teachers based on the model-based inquiry (MBI) approach (Martínez-Chico et al., 2020; Windschitl et al., 2008). Within our project, two of us developed classroom instructional sequences called Sensopills that had a maximum duration of 1.5 h. The sensopart of the name captures three different aspects of the interventions: (1) use of senses to explore phenomena; (2) use of digital sensors to measure variables and collect data; and (3) the sensation, or emotions, experienced by students during the activities. The -pills part of the name captures the short duration and focused nature of these activities. In this study, we report the outcomes of our implementation of the Chewing Gum Sensopill.

**The Chewing Gum Sensopill: Instructional Sequence**

In both classrooms, student groups of 3 or 4 completed the Chewing Gum Sensopill within which we implemented the MBI approach in an instructional sequence divided into two main cycles (Jiménez-Liso et al., 2020a): (1) the inquiry cycle, represented in orange in Figs. 1 and 2), and the modelling cycle, represented in green. The two cycles involved 16 student tasks as shown in the orange and green rectangular boxes in Fig. 1. Students responded to each task individually and then shared their responses in small groups, before discussing them with the whole class.

The white ovals within the inquiry and modelling cycles in Fig. 1 represent the aim of each step in the instructional sequence. For each aim, we designed some tasks. The ten inquiry tasks are shown in the orange boxes in Fig. 1. The main aim of the inquiry cycle was to help to

---

1 The tasks, the phases of inquiry (boxes), and their objectives (ovals) are numbered in the cycle. Along the text, we only use these three numbers in order for the readers to identify the exact moment of the cycles with which we are referring to.
students compare their hypotheses (T4) with evidence (T7), build new descriptive knowledge (T10), and recognize the need of a model, represented by the green cycle in Fig. 1, that can explain their science inquiry outcomes (T11, oval 7; green box 11).

Fig. 1  Chewing Gum Sensopill, inquiry cycle (orange), and modelling cycle (green)
Research Participants

We invited students involved in our Chewing Gum Sensopill to take part in our research before commencement of the instructional activities. This was achieved through a short presentation to two secondary school classes to explain the nature of our MBI instructional sequence and our research. A non-probabilistic convenience sampling method was used to select student participants based on availability and willingness to take part in the study. Two groups of secondary school students aged between 13 and 14 years (23 males and 18 females; 41 in total) in the presence of their science teachers (two female teachers, approx. 40 years of age) were invited to participate in the research, and all students and their parents or carers provided consent to participate in the study. None of the students had any prior experience with acid-base curriculum involving the inquiry-based teaching approaches used in the study (Table 1).

Heuristic Device for Evaluating Students’ Engagement

The heuristic designed for data collection included some tasks done by students from the MBI instructional sequences including the student self-report questionnaires (T17), collected students’ drawings of acid-base models (T12–T15), students planification of experimental designs (T5) to contrast their hypothesis (T4), and video recordings of students completing the Chewing Gum Sensopill for the evaluation of the behavioural dimension of students’ engagement. Table 2 overviews the alignment between heuristic tasks (column 2) and the three dimensions (column 1) of engagement dimensions from our theoretical framework presented earlier in the manuscript. The last two columns represent the nature of data collected (column 3) and the timing of the instructional sequence (column 4).

Emotions Questionnaire

To measure emotional engagement, we analysed the students’ answers to the last task (T17) of the instructional sequence in which students self-report on their emotions in a questionnaire (Appendix). Nine emotions (rejection, concentration, insecurity, interest, boredom, confidence, satisfaction, dissatisfaction, and shame; Martínez-Chico et al., 2020; Windschitl et al., 2008) were presented in this questionnaire from which students had to choose at least one emotion label related to all the Sensopill tasks following the sequential order of the inquiry cycle. The second column of the questionnaire (Appendix) shows in chronological order of inquiry cycle the number and a reminder of each task, followed by the nine emotions to choose (fourth column).

Statistical analyses of questionnaire data include, firstly, percentages of students who state to have felt each of the emotions (once or twice or more) during the whole instructional sequence (Fig. 3); secondly, the percentages of students who state to have felt emotions in each tasks (Table 3); and, thirdly, the significant correlations among emotions (Table 4).

Table 1  Descriptions of participants in this study

| Classroom code | Educational level (students’ age) | Number of students ($n=41$) | Total time in hours (schedules) |
|----------------|----------------------------------|----------------------------|--------------------------------|
| SSC1           | Year 10, KS4 (14 years old)      | 20                         | 1.47 h                         |
| SSC2           | Year 9, KS3 (13 years old)       | 21                         | 1.35 h                         |
| Engagement dimensions | Heuristic | Data collected | Timing of the instructional sequence |
|-----------------------|-----------|----------------|---------------------------------------|
| Emotional             | Self-report questionnaire (2nd Part, Appendix 1) | Emotions chosen by students in key tasks of the inquiry instructional sequence (orange cycle) | At the end of the sequence (T17) |
| Behavioural           | Video recordings | Students and teachers’ time spent in talking and silence Students’ assessment of their experimental designs | Throughout the whole session T5, T6, T7 |
| Cognitive             | Self-regulation questionnaire (1st Part, Appendix 1) | Students’ self-reflection of learning about their knowledge before and after the sequence on key ideas | At the end of the sequence T17) |
|                       | Drawings   | Students’ assessment of their models to explain dilution or neutralization (initial and final) | T12 and T15 |
|                       | Video records |                                                          |                                      |
To validate the questionnaire, an iterative process of review by the researchers has been carried out, until a total consensus of the nine items (inspired on inquiry tasks). Reliability has been assessed using Kuder-Richardson’s coefficient (0.853), which we consider an acceptable value due to the exploratory character of our study (Morales-Vallejo, 2008). To improve the reliability of our questionnaire, we decomposed it into nine sub-questionnaires, focusing on how individuals experienced a single emotion based on their responses to each item. In this case, we obtained a Kuder-Richardson’s coefficient value that is acceptable for most of the emotions (>0.839), except for shame, dissatisfaction, and insecurity. The low reliability coefficients for these three emotions can be explained by small number of students’ responses and their homogeneity (96.7% of the cases answered not having felt those emotions).

**Video Recordings of Classroom Interactions** Two Chewing Gum Sensopill sessions were video recorded producing 2.82 h of video data. Analysis of video recordings was performed with the aid of the ATLAS.ti software, version 7.5.4, which allowed us to perform a rich and deep description of the videos under study by triangulation between researchers. Bellocchi et al., 2017; Olitsky & Milne, 2012 and Jiménez-Liso, Gómez-Macario, et al., 2020; Osborne, 2014 established codes and independently coded the videos. Any discrepancies in codes were discussed in meetings, and a consensus was reached on all coding. In order to guarantee the stability of the data (interpersonal and temporal validity) to the coding, the researchers repeated the grouping process 1 month later, not detecting significant variations.

To determine if it was possible to work with the data obtained in the two sessions as a single group, and to establish if there were significant differences, we employed the Friedman test. This analysis establishes if there are significant differences between paired data series for each category, belonging to different samples. As a lack of differences between the data from the two sessions was demonstrated (level of significance $\alpha = 0.05$), analyses considering a single sample comprising the sum of the three were performed.

**Students’ Acid-Base Models (Initial and Final Drawings)** During the Chewing Gum Sensopill, students documented their answers to each task in small notebooks provided by the researchers. In tasks 12 and 15, student groups were asked to draw what happens when vinegar was added to the water, then when chewing gum was added to the vinegar/water solution, and when toothpaste was added to the vinegar/water solution. Student notebooks containing their models were collected at the end of the lesson. These drawings were analysed to establish the effectiveness of the instructional sequence in relation to the cognitive engagement.

All students’ acid-base models (drawings) were scanned and digitized for coding with the aid of ATLAS.ti (7.5.4 version). As in the instructional sequence, there were two tasks where the students had to draw their acid-base models (initial, T12 and final, T15), the first code was to label the drawings in each task. Secondly, the next codes were by the acid-base content used in order to understand how explanatory the drawings are. Figure 2 shows the screenshot of an initial drawing (small group #2 in year 10, KS4) coded as mixture of particles (A, V, P), and the students’ explanation seems to be which particle predominates. Our interpretation of this drawing (Fig. 2) will be discussed in greater depth in the results section along with analysis of video recorded student explanations.
Analysis and Results

The results of the study are presented in sections corresponding to each dimension of student engagement based on our theoretical framework. Overall, we report that our short MBI instructional sequence develop students’ emotional engagement because most of them recognize to having felt interest, concentration, and satisfaction and few students reported boredom, shame, or rejection during the teaching. They spent most of time working in small groups and sharing-discussing their hypothesis (T4), planning and evaluating their experimental designs (T5), and building models to explain acid-base phenomena together (T12–T15) which highlight behavioural and cognitive dimension of students’ engagement in our Chewing Gum Sensopill.

Emotional Engagement

We outline students’ self-reported emotions from two different points of view: (1) emotions related to overall student experiences with the instructional sequence (global) and (2) emotions felt at each task of the development of the instructional sequence. Analysis of the information obtained will allow complementary conclusions to be drawn with respect to what the students felt.

Emotions Reported Throughout the Instructional Sequence (Global) Figure 3 presents the number of students (in percentages) who claimed to have felt each of the listed emotions, regardless of the task during which the emotions were experienced. Here, we have distinguished between those students who recognized a specific emotion only once from those who state it more than once. From Fig. 3, we can discern that two of the emotions predominate widely over the rest: interest and concentration. This statistical snapshot seems to indicate that sequence engaged students (interest and concentration). Boredom, along with insecurity, rejection, dissatisfaction, and shame, with low frequencies, is not considered by us to be negative emotions.
Emotions Reported at Each Task of the Instructional Sequence  Figure 3 do not provide us relevant information unless we look at what task were students reported in (Table 3): Highest scores of boredom were in T4 (hypotheses) and T8 (data analysis to check them), both tasks where we stopped to brainstorm and share ideas (hypotheses and data analysis to test them) that were perceived as boring by some students (12.5%).

Over 50% of students recognized felt interest and 30–40% felt concentration in all the tasks of the instructional sequence. Based on the nine emotion labels offered, in task T7 (data collection) most of students recognized felt interest (67.5%), concentration (45%), and confidence (22.5%) that are the highest percentages of these labels by task and the lowest percentages of the labels insecurity (0%) and boredom (5%). We can analyse the correlations between the nine labels of emotions and correlations in T7 (Table 4): interest negatively correlates with rejection and boredom (−0.3), and we found a moderate positive correlation between confidence and satisfaction (+0.5). These results can mean task T7 (data collection), in which the students verified that the results were not as they expected, were the task most engaged for students.

Following with correlations between emotions reported by students, confidence has a positive moderate correlation with interest in items T4, T5, and T8, three tasks of brainstorming hypotheses, experimental designs, and data analysis, which seems to show that the climate of confidence is essential for contrasting their own ideas with those of their classmates. Confidence also positively correlates with satisfaction in T2, T3, and T7 three tasks about the use of pH meter (hands-on tasks). Interest and boredom have negative moderate correlations in most of the items.

This empirically confirms expected relationships among emotions, some of them favourable to an atmosphere for learning, such as tandems interest-confidence or satisfaction-confidence; others that difficult learning, such as rejection produced by insecurity that can block learning process (in six students who indicated); as well as the antagonistic relationships between boredom and interest.

Behavioural Engagement

Productive Use of Class Time  We have accounted for the minutes that a student spoke aloud to the whole group (second column of Table 5) and working in a group (third column); that the Sensopill teacher of instructional sequence spoke (fourth column) to set out a particular activity of the sequence and to highlight or repeat student commentaries or explain something, when the usual teachers intervened (generally their role was as viewer, 5th column); as well as silences and murmurs that could not be counted in the previous columns.

| Table 3 Percentage of students who felt each emotion at each instruction sequence task (higher scores by rows in bold) |
|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
|                  | T1   | T2   | T3   | T4   | T5   | T6   | T7   | T8   | T9   |
| Interest         | 60.0 | 67.5 | 57.5 | 62.5 | 57.5 | 50.0 | 67.5 | 47.5 | 62.5 |
| Concentration    | 42.5 | 30.0 | 35.0 | 42.5 | 42.5 | 32.5 | 45.0 | 42.5 | 37.5 |
| Satisfaction     | 20.0 | 20.0 | 20.0 | 25.0 | 25.0 | 25.0 | 12.5 | 17.5 | 27.5 |
| Confidence       | 15.0 | 20.0 | 17.5 | 17.5 | 17.5 | 10.0 | 22.5 | 15.0 | 20.0 |
| Boredom          | 10.0 | 5.0  | 5.0  | 12.5 | 2.5  | 7.5  | 5.0  | 12.5 | 5.0  |
| Insecurity       | 2.5  | 2.5  | 5.0  | 0.0  | 5.0  | 7.5  | 0.0  | 5.0  | 2.5  |
Table 4  Significant correlations among emotions

|                | Rejection | Concentration | Insecurity | Interest | Boredom | Confidence | Satisfaction | Dissatisfaction | Shame |
|----------------|-----------|---------------|------------|----------|---------|------------|--------------|-----------------|-------|
| Rejection      |           |               |            |          |         |            |               |                 |       |
| Concentration  |           |               |            |          |         |            |               |                 |       |
| Insecurity     |            |               |            |          |         |            |               |                 |       |
|                 | T5: + 0.7  | T9: + 0.7     |            |          |         |            |               |                 |       |
| Interest       |           |               |            |          |         |            |               |                 |       |
|                 | T7: −0.3   |               |            |          |         |            |               |                 |       |
| Boredom        | T4: −0.3   | T8: −0.3      |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
|                |            |               |            |          |         |            |               |                 |       |
| Confidence     |           |               |            |          |         |            |               |                 |       |
|                | T4: + 0.4  | T5: + 0.4     | T8: + 0.4  |          |         |            |               |                 |       |
| Satisfaction   |           |               |            |          |         |            | T2: + 0.6     | T3: + 0.4       | T7: + 0.5 |
| Dissatisfaction|           |               |            |          |         |            | T8: + 0.7     | T9: + 0.7       | T8: + 0.4 |
| Shame          |           |               |            |          |         |            |               |                 |       |
|                | T8: + 0.7  | T9: + 0.7     |           |          |         |            |               |                 |       |
Table 5  Time spent by each participant (along with silences, murmurs) in the instructional sequence (Sensopill)

| Time employed session | Students (in seconds) | Group work of students (inaudible) | Sensopill teacher | Usual teachers | Silences | Murmurs (inaudible) | Total time in seconds |
|-----------------------|-----------------------|------------------------------------|-------------------|----------------|----------|---------------------|-----------------------|
| SSC12 (15 years old)  | 694" (14.3%)          | 1707" (35.1%)                      | 2232" (45.9%)     | 41" (0.9%)     | 48" (1.0%) | 140" (2.9%)         | 4862"                 |
| SSC1 (16 years old)   | 609" (11.5%)          | 1449" (27.4%)                      | 2682" (50.6%)     | 16" (0.3%)     | 66" (1.3%) | 474" (9.0%)         | 5296"                 |
| n=20                  |                       |                                    |                   |                |          |                     |                       |
| Average               | 12.9%                 | 31.2%                              | 48.3%             | 0.6%           | 1.1%     | 5.9%                |                       |
The highest percentage of participation corresponds to the intervention of the Sensopill teacher of the instructional sequence (48.3%), followed by the time spent working in groups. Students spent half of the time during the 85 min approximately talking loudly (12.89%) or among them (31.2%) performing activities in groups, proposing hypothesis, developing experimental designs, and constructing and evaluating their models. The Sensopill teacher spent half of the time speaking; however, this helped the students to express their ideas, from 11.5% (year 11, KS4) to 14.3% (year 10, KS3).

**Experimental Designs Proposed by the Students** One group proposed the hypothesis that chewing gum absorbed moisture and dried the mouth, and this would cause an increase in pH. To test their hypothesis, the students proposed measuring the saliva with a pH indicator before (they had previously checked that the pH was close to 7) and after having a meal and then drying the tongue of saliva (absorbency), before measuring again with pH indicator paper. While discussing this experimental design, a girl directly completed the experiment as it was being proposed and said that the result was the same as with saliva. Another group proposed chewing gum between times for this hypothesis to check if there was more in either case.

In the case of hypothesis that more saliva is generated (pH = 7) and that makes the pH increase (acidic medium), another group proposed we eat fruit, spit saliva in a glass, chewing gum and again spit saliva in another glass and test the pH in both glasses with pH indicator paper (or a pH meter). Thus, they would compare the initial pH that was supposed to be acid and the final pH that they predicted would be neutral.

The transcript excerpt below presents a conversation around the experimental design (Table 6).

The importance of students being the ones who propose experimental designs is that they can be engaged in the process, not only in the surprising result. We cannot expect that students go through the entire research process, but this makes sense, as by giving them the chance to make mistakes, they can discover whether their designs measure or what they are intended to (plausibility and effectivity of the experimental designs).

**Cognitive Engagement**

Many of the students’ initial pictures (T12), despite the inclusion of drawings of particles or molecules, do not explain what happens when an acid substance is added to the water and then an alkali added to them (Fig. 4).

After checking that vinegar produces an acid medium (pH < 7) and that toothpaste alkalines it (pH > 7), many of their pictures did not even propose differences between adding an acid to the water or an alkali, such as in the case of toothpaste (Fig. 5).

These results show the initial difficulties that students experience when they have to draw explanatory pictures or develop initial models on acid-base phenomena, except Ivan’s group that codified toothpaste (P), vinegar (V), and water (A) and proposed a mix. In his explanation, he stated that the pH value would depend on what compound predominated: if water predominated, the pH would be 7; if vinegar predominated, the pH would be lower than 7 (acidic medium); if toothpaste predominated, the pH would be higher (alkaline medium, Fig. 6).
Sensopill teacher posed the following

A student group proposed

Omaya’s group proposed

The Sensopill teacher asked

Another group of students continued

Sensopill teacher asked again

The Sensopill teacher returns to the proposal

Finally, a fourth group pointed out

This time the Sensopill teacher emphasized the importance of the moment at which the measurement was taken

In this way we test if chewing gum works, but not if this is due to the increase in saliva (dilution) or reaction with the acid (neutralization).

We add an acid substance (like saliva after having a meal) in a glass, for example, lemon, vinegar, and we measure the pH, add water (pH = 7), and we measure the pH; the more water, the more neutral.

We crush chewing gum, add water; it dilutes and after inserting the pH-meter, we measure the chewing gum pH.

What will be the result of this? This will have increased – increased or decreased?

In a glass with a tap (such as those from McDonald’s for Coca-Cola) to introduce more food to the pH-meter, more saliva or water, as they show the same pH, shake and after that measure the pH.

What will be the result of this? This will have increased – increased or decreased? Increased, as it is more acid. Ah? Goes down!

you need chewing gum... Ah we crush it, measure the pH, and add to it.

In an environment we have acid and we eat chewing gum and... after that we have something acid, vinegar... add vinegar, lemon, now we have acid and add crushed gum.

Check how many times it is necessary to measure the pH, we have commented on that. To measure the pH of water in the beginning, of the acid, when we add water again, of the crushed chewing gum to check its pH, and when it is added to the acid solution. Now we start to measure and – surprise! – crushed chewing gum is acid, and when we add only water the pH does not increase. Then? If we add toothpaste?
The students’ initial models were essential steps in facilitating the introduction of our acid-base model (T15, Fig. 1), in which the reaction between acid (triangles) and alkali (PAC-MAN) or water (circles) is explanatory depending on which substance is in excess.

After the introduction of PAC-MAN model, all the students’ final pictures (like Fig. 7) show they were able to explain the acid-base process that they did not before. That is an evidence of their cognitive engagement and shows the model was very clarifying for the students and had sense for them.

To determine whether and how activities engage students in scientific thinking and reasoning, it is essential to know what students are doing during the activities and not just how they perform on assessments after these activities; our previous results show...
that tasks have enhanced students’ engagement in scientific modelling and understanding of acid-base ideas.

**Discussion**

As Sinatra et al. (2015) note, engagement in scientific practices as a whole has not been extensively researched, and therefore the specific connections between the behavioural, cognitive, emotional, and agentic dimensions of engagement remain largely speculative at present. For this reason, in this paper, we measure engagement in an integrated way that takes into account the multiple interaction dimensions of engagement. Furthermore, our study adopts measures which offer minimal disruption to the flow of student engagement during science learning because the parts of our heuristic that evaluates students’ engagement form part of the instructional sequence delivered by teachers and enacted with students. One key contribution that emerges from our study is that heuristics can be effective for both instructional and research purposes, thereby reducing burden on research participants, while producing meaningful information about the interrelated dimensions of students’ engagement in science.

A second novel contribution that our study provides is an answer to Smallhorn et al.’s (2015) question about the minimum time required to achieve student engagement. In our study, the short MBI instructional sequence took 1.5 h and revealed evidence of student engagement. We are thereby able to offer an initial answer to Smallhorn et al.’s question based on the length of the instructional sequence (i.e. 1.5 h) adopted in our study. We note that due to the short duration of our instructional sequence, we cannot make claims about an enduring sense of engagement with school science. Further research that adopts extended applications of our MBI sequence and measures of engagement over longer periods of time is necessary to understand what impact, if any, the sequence can have on enduring engagement.

Our short MBI instructional sequence was designed to address student disengagement with school science, a problem which concerns not only the school where this study took place but a shared international concern of teachers, researchers, and policy makers (Lyons & Quinn, 2010). Due to the usual overemphasis of research on either cognitive or behavioural engagement, we adopted a three-dimensional model of engagement encompassing emotional, cognitive, and behavioural dimensions to address the need for holistic understandings of engagement in learning science (Fredricks...
et al., 2016; Olitsky & Milne, 2012). We also studied the effectiveness of our instructional sequence through learning-related multidimensional engagement, an under-researched area in relation to the MBI approach (Inkinen et al., 2020). Finally, the main contribution of this study has produced and used the heuristic device that teachers and researchers can use to understand student engagement during science inquiry. Our heuristic is designed to gather data continuously during instruction with minimal disruption to the learning and teaching sequence. The heuristic can be used by teachers (and also by students) to gain multi-level understandings about engagement by focusing on individual, group-level, or class-level analysis of responses (Olitsky & Milne, 2012).

Conclusions

As we have reported in this study, our MBI instructional sequence was effective because the majority of students (over 50%) experienced interest, concentration, and satisfaction during all of the tasks in the MBI sequence and few students (less 20%) reported boredom, rejection, shame, dissatisfaction, and insecurity by tasks (and in the whole sequence). These data show a final snapshot of the whole group of students’ emotional engagement in our short MBI instructional sequence, a wider outcome than the ones that exclusively associate with interest (Inkinen et al., 2020; Olitsky & Milne, 2012) but at a specific moment, of the entire class group (panoramic picture).

The emotional responses have been analysed task by task in response to the Inkinen et al., 2020 claim about the need to account for why a student would become absorbed in one task rather than another. The emotional responses show the task data collection as the task of the inquiry sequence when more students were engaged as shows the high number of students that reported concentration, confidence, and interest, results which also correlate negatively with boredom and rejection. Confidence has a positive moderate correlation with interest in the three collective tasks where students share their hypotheses (T4), experimental designs (T5), and data analysis (T8). Confidence also correlates positively with satisfaction in T2, T3, and T7 three hands-on tasks related to the use of pH meter. These results seem to show the importance of promoting a climate of confidence, but we do not know if confidence is a prerequisite to develop inquiry-based sequences or as a consequence of implementing inquiry (Wolkenhauer & Hooser, 2017). In view of the relationship between the results of confidence and satisfaction found in the hands-on activities in the inquiry-based sequence and the interest when contrasting their own ideas with those of their classmates, we can conclude that confidence is crucial in both hands-on and minds-on task throughout the inquiry-based sequence, but we cannot conclude in which of them the students engagement is greater. This distinction might be controversial, as Inkinen et al. (2020) highlight modelling enhance the emotional situational engagement more than inquiry, but in other studies inquiry is better valued by students than modelling tasks (Munoz-Campos et al., 2018).

Furthermore, our MBI teaching promotes behavioural engagement because it is a student-centred instructional sequence as we have verified through measuring the time spent by the students in participating actively (50% of the total instruction time) and the students’ nonparticipation minutes taken advantage by the teacher exclusively to point out the students points of view and to ask them about each other. This balance between participation and nonparticipation is the dialectic definition of behavioural engagement (Hickey & Zuiker, 2010). Secondly, for behavioural engagement was crucial the task#5 in which students plan how to
find evidence for the initial problem (similar to other proposed by Crujeiras-Pérez & Jimenez-Aleixandre, 2017), because they had to evaluate the plausibility and effectivity of their own and others proposals to build a consensus experimental design.

At last but not least, MBI instructional sequence promotes cognitive engagement because after the instruction, students were able to both improve their initial non-explanatory models and explain the acid-base process that they were not able to do before. These results are interesting for science education because these confirm that modelling enhances students’ scientific knowledge by engaging students in thinking, expressing, and sharing their understanding of how a certain phenomenon is and how it works (Windschitl et al., 2008). The collective construction of the triangles-PACMAN model is useful to understand acid-base phenomena, to build the huge chemical change model, and to learn about the process of modelling.

In addition to the results that emerge from the analysis, we offer to researcher and science teachers a heuristic for evaluating students’ engagement in situ, during the implementation of instructional sequence, and a proposal for data processing that can be exportable to other evaluation of educational programmes. This is a relevant contribution considering the limited range of specific and transferable assessment proposals that permit the analysis of engagement in situ by using the students’ tasks productions: their hypothesis, their experimental designs, their initial and final models, and their self-reports.

Limitations

The results of this study are on a small scale (41 students and one teacher). As a descriptive study, it has allowed us to characterize science students’ multidimensional engagement in a Spanish classroom context. Our findings are encouraging and suggest that future large-scale application of our heuristic is warranted with a greater number of teachers.

We cannot lose sight of the fact that the instructional sequence analysed is a short duration (1.5 h) sequence whose objective has not been to research how many students or what (learning progression) they have learned but to describe students’ engagement as a multidimensional phenomenon through an heuristic immersed in the instructional sequence, with sense for the students and easy to apply for their teachers.

We identify the source of the engagement is the MBI instructional sequence that includes interactions between students and also with the classroom teacher. In future researches, we want to compare students’ engagement in the same learning approach with the same teacher across different topics to analyse the effect of the topic and the teacher’s triggers on students’ engagement.

Finally, one additional challenge is the current pandemic situation that forces many science teachers to have online or dual classes. It would be advisable to extend this study to these virtual environments and analyse the influence of online classes on the multidimensional aspects of student engagement with science.

Supplementary Information  The online version contains supplementary material available at https://doi.org/10.1007/s11165-021-10010-0.

Acknowledgements  Thanks to the students and teachers of the IES Murgi (El Ejido, Almeria) as well as to the teachers Lucia, Isabel, and Carmen and, also, Esteban and Yolanda from our Master Degree for their participation.
Author Contribution  M Rut Jimenez-Liso and Maria Martinez-Chico designed and implemented the instructional sequence in the IES Murgi (Secondary School in El Ejido, Almeria, Spain). Rut, Maria, and Rafael Lopez-Gay collected and analysed the data (self-report questionnaire, video recordings, students’ drawings, etc.). Alberto Bellocchi contributed to the analyses, results, conceptual framework, ensuring that evidence-based claims were made, making revisions to logical sequencing of ideas, editing manuscript drafts, and providing conceptual input to the research.

Funding This paper is partially funded by MINECO (with FEDER funds, EDU2017-82197-P), CEIMAR-UAL, and Ministerio de Ciencia, Innovación y Universidades (PRX19/00364) of the Spain Government.

Declarations

Ethical Issues and Conflicts of Interest  There are no conflicts of interest, and ethical precautions were taken with the students and their parents’ consents for participation and publication.

References

Antúnez, Á., Cervero, A., Solano, P., Bernardo, I., & Carbajal, R. (2017). Engagement: A new perspective for reducing dropout through self-regulation. In J. A. González-Pienda, A. Bernardo, J. C. Núñez, & C. Rodriguez (Eds.), Factors affecting academic performance (pp. 25–46). Nova Science Publishers.

Arthur, D. (2005). The effect of inquiry-based instruction on students’ participation and attitudes in a third grade science classroom. University of Central Florida.

Bellocchi, A., Quigley, C. F., & Otrle-Cass, K. (2017). Emotions, aesthetics and wellbeing in science education: Theoretical foundations. In A. Bellocchi, C. F. Quigley, & K. Otrle-Cass (Eds.), Exploring emotions, aesthetics and wellbeing in science education research (pp. 1–6). Dordrecht, The Netherlands: Springer. https://doi.org/10.1007/978-3-319-43353-0_1.

Bevins, S., & Price, G. (2016). Reconceptualising inquiry in science education. International Journal of Science Education, 38(1), 17–29. https://doi.org/10.1080/09500693.2015.1124300.

Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In Handbook of Research on Science Education, Volume II (pp. 515–541). https://doi.org/10.4324/9780203097267.

Crujeiras-Pérez, B., & Jimenez-Aleixandre, M. P. (2017). High school students’ engagement in planning investigations: Findings from a longitudinal study in Spain. Chemical Education Research and Practice, 18(1), 99–112. https://doi.org/10.1039/C6RP00185H.

Duschl, R. A., & Grundy, R. E. (2008). Teaching scientific inquiry: Recommendations for research and implementation. Sense Publishers.

FECYT. (2019). Social perception of science and technology in Spain 2018. https://icono.fecyt.es/sites/default/files/filepublicaciones/20/percepcion_social_de_la_ciencia_y_la_tecnologia_2018_completo_0.pdf. Accessed 31 May 2021.

Fredricks, J. A., Te Wang, M., Schall Linn, J., Hofkens, T. L., Sung, H., Parr, A., & Allerton, J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. Learning and Instruction, 43, 5–15. https://doi.org/10.1016/j.learninstruc.2016.01.009.

Grabau, L. J., & Ma, X. (2017). Science engagement and science achievement in the context of science instruction: A multilevel analysis of U.S. students and schools. International Journal of Science Education, 39(8), 1045–1068. https://doi.org/10.1080/09500693.2017.1313468.

Hickey, D. T., & Zuiker, S. J. (2010). Cross-cultural approaches to measuring motivation cross-cultural approaches to measuring motivation. Educational Assessment2, 10(3), 277–305. https://doi.org/10.1207/s15326977ea1003_7.

Inkinen, J., Klager, C., Juuti, K., Schneider, B., Salmela-Aro, K., Krajcik, J., & Lavonen, J. (2020). High school students’ situational engagement associated with scientific practices in designed science learning situations. Science Education, 2018, 1–26. https://doi.org/10.1002/sce.21570.

Jeong, J. S., González-Gómez, D., & Cañada-Cañada, F. (2016). Students’ perceptions and emotions toward learning in a flipped general science classroom. Journal of Science Education and Technology, 25(5), 747–758. https://doi.org/10.1007/s10956-016-9630-8.
Jiménez-Liso, M. R., Lopez-Banet, L., & Dillon, J. (2020a). Changing how we teach acid-base chemistry: a proposal grounded in studies of the history and nature of science education. *Science & Education, 29*(4), 1291–1315. https://doi.org/10.1007/s11191-020-00142-6.

Jiménez-Liso, M. R., Gómez-Macario, H., Martínez-Chico, M., Garrido Espeja, A., & López-Gay, R. (2020b). Egagrópilas como fuente de pruebas en una indagación. Percepciones de los estudiantes sobre lo que aprenden y sienten. Raptor pellets as evidence in an inquiry-based teaching. Students’ perceptions on what they have learnt and felt. *Revista Eureka Sobre Enseñanza y Difusión de Las Ciencias, 17*(1), 1–18. https://doi.org/10.25267/Rev.

Jiménez-Liso, M. R., Martínez-Chico, M., Avraamidou, L., & López-Gay, R. (2021). Scientific practices in teacher education: the interplay of sense, sensors, and emotions. *Research in Science and Technological Education, 39*(1), 44–67. https://doi.org/10.1080/02635143.2019.1647158.

Lyons, T., & Quinn, F. (2010). *Choosing science: Understanding the declines in senior high school science enrolments*. National Centre of Science. http://www.une.edu.au/simerr/pages/projects/131choosingscience.pdf.

Martínez-Chico, M., Evagorou, M., & Jiménez-Liso, M. R. (2020). Design of a pre-service teacher training unit to promote scientific practices. Is a chickpea a living being? *International Journal of Designs for Learning, 11*(1), 21–30. https://doi.org/10.14434/ijdl.v11i1.23757.

Milne, C., & Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. *Science Education, 91*(4), 523–553. https://doi.org/10.1002/sce20203.

Morales-Vallejo, P. (2008). La fiabilidad de los tests y escalas. The reliability of tests and scales. In P. Morales-Vallejo (Ed.), *Estadística aplicada a las Ciencias Sociales* Statistics applied to the Social Sciences (pp. 3–37). Universidad Pontificia Comillas.

Mostafa, T., Echazarra, A., & Gillou, H. (2018). The science of teaching science practices in *PISA 2015* (issue 188). https://doi.org/10.1787/f5bd9e57-en.

Munoz-Campos, V., Joaquin Franco-Mariscal, A., & Blanco-Lopez, A. (2018). Secondary students’ mental models about milk transformation into yogurt. *Revista Eureka Sobre Enseñanza y Difusión de Las Ciencias, 15*(2), 320110–320124. https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2020.v17.i3.3201.

Murphy, C., & Beggs, J. (2003). Children’s perceptions of school science a study of 8–11 year-old children indicates a progressive decline in their enjoyment of school science. School Science Review, 84(308).

Nasution, W. N. (2018). The effects of inquiry-based learning approach and emotional intelligence on students’ science achievement levels. *Journal of Turkish Science Education, 15*(4), 104–115. https://doi.org/10.12973/tused.10249a.

Nuffield Foundation. (2013). *Model-based inquiry and practical work – An introduction* How this introduction is organised Model-based inquiry and practical work – an introduction Quick start guide to model-based inquiry. https://www.stem.org.uk/resources/elibrary/resource/459821/model-based-inquiry.

OECD. (2019). *PISA 2018 results (volume II): Where all students can succeed*. In *OECD Publishing: Vol. II*. https://www.oecd.org/pisa/publications/PISA2018_CN_IDN.pdf

Olivsky, S., & Milne, C. (2012). Understanding engagement in science education: The psychological and the social. In B. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (pp. 19–33). Springer. https://doi.org/10.1007/978-1-4020-9041-7_2.

Osborne, J. (2014). Scientific practices and inquiry in the science classroom. In N. G. Lederman (Ed.), *Handbook of Research on Science Education* (II ed., pp. 579–599). Lawrence Erlbaum Associates Publishers. https://doi.org/10.4324/9780203097267.ch29.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (p. 8). Nuffield Foundation, January. http://www.fisica.unina.it/traces/attachments/article/149/Nuffield-Foundation-Osborne-Dillon-Science-Education-in-Europe.pdf%5Cnpapers2://publication/uuid/FA17ED57-71AF-429E-B7E5-D9E33DA4A538.

Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. *Journal of Educational Psychology, 105*(3), 579–595. https://doi.org/10.1037/a0032690.

Riffert, F., Hagenauer, G., Kriegseisen, J., & Strahl, A. (2020). On the impact of learning cycle teaching on Austrian high school students’ emotions, academic self-concept, engagement, and achievement. *Research in Science Education, https://doi.org/10.1007/s11165-020-09918-w.*

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist, 50*(1), 1–13. https://doi.org/10.1080/00461520.2014.1002924.
Smallhorn, M., Young, J., Hunter, N., & da Silva, K. B. (2015). Inquiry-based learning to improve student engagement in a large first year topic. *Student Success, 6*(2), 65–72. https://doi.org/10.5204/ssj.v6i2.292.

Tourón, J., López-González, E., Lizasoain Hernández, L., García San Pedro, M. J., & Navarro Asencio, E. (2018). Spanish high and low achievers in science in PISA 2015: Impact analysis of some contextual variables. Revista de Educacion, 2018(380). https://doi.org/10.4438/1988-592X-RE-2017-380-376.

Vázquez, Á., & Manassero, M. A. (2008). El declive de las actitudes hacia la ciencia de los estudiantes: un indicador inquietante para la educación científica. The decline in students' attitudes towards science: a disturbing indicator for science education. *Revista Eureka Sobre Enseñanza y Divulgación de Las Ciencias, 8*(3), 274–292. https://doi.org/10.25267/rev_eureka_ensen_divulg_cienc.2008.v5.i3.03.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education, 92*(5), 941–967.

Wittmann, S. (2011). Learning strategies and learning-related emotions among teacher trainees. *Teaching and Teacher Education, 27*(3), 524–532. https://doi.org/10.1016/j.tate.2010.10.006.

Wolkenhauer, R., & Hooser, A. (2017). “Inquiry is confidence”: How practitioner inquiry can support new teachers. *Journal of Practitioner Research, 2*(1), 5. https://doi.org/10.5038/2379-9951.2.1.1028.

**Publisher’s Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.