Research article

On the potential of live weighing as evidence of existence of gases

C.B. Vik[1*], E.I. Romijn[1], and N.K. Rossing[2]

[1] Department of Teacher Education, Norwegian University of Science and Technology, Norway.
[2] The Resource Centre for mathematics, science and technology in schools, Department of Physics, Norwegian University of Science and Technology, Norway.

*Corresponding author. E-mail: camilla.berge.vik@ntnu.no

The gas concept is fundamental for STEM learning, yet many hold misconceptions about gases, such as gases not having material nature nor being conserved in chemical reactions. Some suggest perceptual evidence of existence (such as colour or smell) is key to acknowledging the material nature and subsequently the role of gases in mass conservation. In this paper we did a preliminary exploration of whether a real-time scale with graphical interface can serve as evidence of existence of gases. To do so, we designed and conducted a teaching unit in which preservice primary science teachers (n=4) used a real-time scale to perceive weight change during two chemical reactions in which gases evolved or absorbed. The teaching unit was audio recorded and observed. We found that two important design elements, when introducing live scales were a) hypothesis line graphs to familiarize with the graphical interface and b) the choice of live (as contrast to logged) measurements to promote learners' attention during observation. Learners displayed subtle signs of trust in and familiarity with the instrument, indicating a potential for the live scale as evidence of existence of gases.

Keywords: live scale, material nature, gas

DOI: 10.5324/njsteme.v10i1.6598

1 Introduction

1.1 Evidence of existing gases

The gas concept is fundamental for STEM learning (Çetin et al., 2009); for example, that gases have weight[1] (and take up space) and therefore can be classified as matter (Smith et al., 2006), that gaseous products are material (Mas et al., 1987) and that mass is conserved in chemical reactions involving gases. Recognizing that gases are material is hypothesised to be a prerequisite to acknowledge mass conservation in reactions in which gas is a reactant or product, for example to recognize oxygen as a material substance in combustion reactions (Mas et al., 1987).

As most gases are invisible, they often escape our attention (Kind, 2004). Alternative conceptions related to gases are, for example, that "[g]ases have no mass" (Azizoğlu & Geban, 2004, Table 1), that gases do not have weight (Stavy, 1990), that gases are not materials / substances (Allen, 2020, p. 95; Barke, 2009, p. 50) and that gases have negative weight (Driver, 1994). Learners also struggle with the materiality of gases during processes. For example, learners may state that gases simply disappear during combustion (Allen, 2020, p. 96) or that mass decreases when solid iron burns due to decreasing volume (Basheer et al., 2018). Mas et al. (1987) found that pupils at secondary level largely did not use the principle of mass conservation in processes where gases took part, and that this was due to their preconception that because gases rise, they do not have weight and therefore no mass (Mas et al., 1987). He claimed that overcoming the notion that gases are substances without weight was fundamental to explain chemical reactions with gaseous substances, and thus the conservation of mass in reactions involving gases (Mas et al., 1987). According to Kind (2004, p. 44), even though learners may appreciate the role of oxygen during combustion, the conception that gas has no mass makes students not expect a mass increase in the oxidized product.

Literature on exactly how to address misconceptions about the mass of gas is termed scarce (Mayer, 2011), yet includes weighing before and after a carbon dioxide sublimation or reaction between a solid and a gas (Mayer, 2011), weighing a party balloon before and after inflation (Allen, 2020, p. 112) and weighing steel wool before and after combustion (Barke, 2009, pp. 48–49). Mas et al. (1987) emphasized the importance of perceiving the gas to appreciate the material nature of gases and subsequently mass conservation: The less the learner perceived the gas or gaseous process, the more likely the learner landed on non-conservation of gases (Mas et al., 1987). This is in line with Stavy (1990), who found that learners were more likely to believe the presence of coloured gases (such as iodine) than invisible gases (such as acetone); "Children believe matter exists only when there is evidence of its existence." (Stavy, 1990, p. 257). Colour was better evidence of existence than smell (Stavy, 1990). One potential way to appreciate mass conservation in chemical processes is therefore accepting the materiality of gases through evidence of existence. In this study, we explore whether live

---

[1] In the literature sometimes weight and mass are used as synonyms, and therefore the use of these words might differ from the definitions we will use in this paper. In this paper we will use word weight about the quantity that is measured by a scale, which is related to the normal force, and therefore is affected by other forces such as gravity and buoyancy. While mass is a property of matter.

weighing (continuous weight measurements that are depicted graphically in real time) during a chemical process might offer the potential of evidence of existence of gases, to add to colour, smell and weighing before and after a process.

1.2 Introducing new instruments for learners

To theoretically frame our study, we rely on the characterisation by Kraus (2024) of observation in science. Introducing new instruments does not directly imply learners observe the phenomenon; instruments must be trusted by their users (Kraus, 2024) and users must be willing to undertake conscious perception (Kraus, 2024) of the rate of change in weight. Throughout the paper we will introduce concepts from Kraus (2024), along with other literature, to support our choices and interpretations.

As live weighing equipment we used a home-built live scale (Rossing et al., 2024) based on the micro:bit infrastructure, which is widely distributed in the Norwegian context (super:bit, 2025). The approach is equally feasible with Arduino or general sensors offered for pedagogical contexts that consist of a scale with a suitable precision and a direct translation to a graphical interface. Both micro:bit and Arduino are programmable microcontrollers, often used to learn about technology and programming.

As target group for our study we chose pre-service primary science teachers, for convenience and availability reasons. Pre-service primary teachers are learning science, technology and programming in an integrated manner, along with the Norwegian demand of an integrated curriculum (Vinnervik & Bungum, 2022) and are therefore situated in a STEM learning context.

In this study we investigated the following research question:

> *Does live weighing have the potential to serve as evidence of existence of gases, and if so, how?*

Our study is of an exploratory and preliminary nature. To the best of our knowledge, there are no studies on the integration of live scales in STEM classrooms. Therefore, to address our research question, we both discuss the integration of the scale into a teaching unit and observations of the conducted unit.

Below, we first describe important design choices in the teaching unit. Secondly, we respond to the research question by describing the testing of the teaching unit including its method and results.

2 Part 1: Integrating live weighing into a STEM teaching unit

2.1 The teaching unit

The overall purpose of the teaching unit was to use live weighing during a process to help learners observe that if gas is formed, the weight decreases, if gas is a reactant, the weight increases, and thus to offer evidence of existence of gases. We therefore chose one reaction in which gas is product and one in which gas is a reactant, where each case acted as a clarifying contrasting example (Kraus, 2024, p. 1040) for the other. The reactions had to be fast enough for changes to occur within a few minutes, so to have time to run the reactions a couple of times each during a typical classroom unit of 45 minutes, with the weight change needed within the range of the live weighing equipment (Time et al., 2026). Our choice therefore fell on the vinegar-soda reaction as gas production process,

$$\begin{gathered}\text{vinegar (aq)} + \text{soda (s)} \rightarrow \\ \text{sodium acetate (aq)} + \text{water (l)} \\ + \text{carbon dioxide (g)},\end{gathered} \tag{1}$$

and the steel wool combustion reaction as gas consumption process,

$$\text{iron (s)} + \text{oxygen (g)} \rightarrow \text{iron oxide (s)}. \tag{2}$$

The teaching unit is shown schematically in Figure 1, with protocol for each element in Table 1. At the beginning of the teaching unit, learners assembled (see Rossing et al. (2024) for technical details) and tested the live weighing instrument to familiarize themselves with it. Thereafter, for each of the two processes, learners 1) observed the process without weighing, 2) co-drew the weight graph they anticipated after observing the process and 3) observed the process combined with live weighing.

2.2 Designing the unit for familiarity with and trust in the new instrument

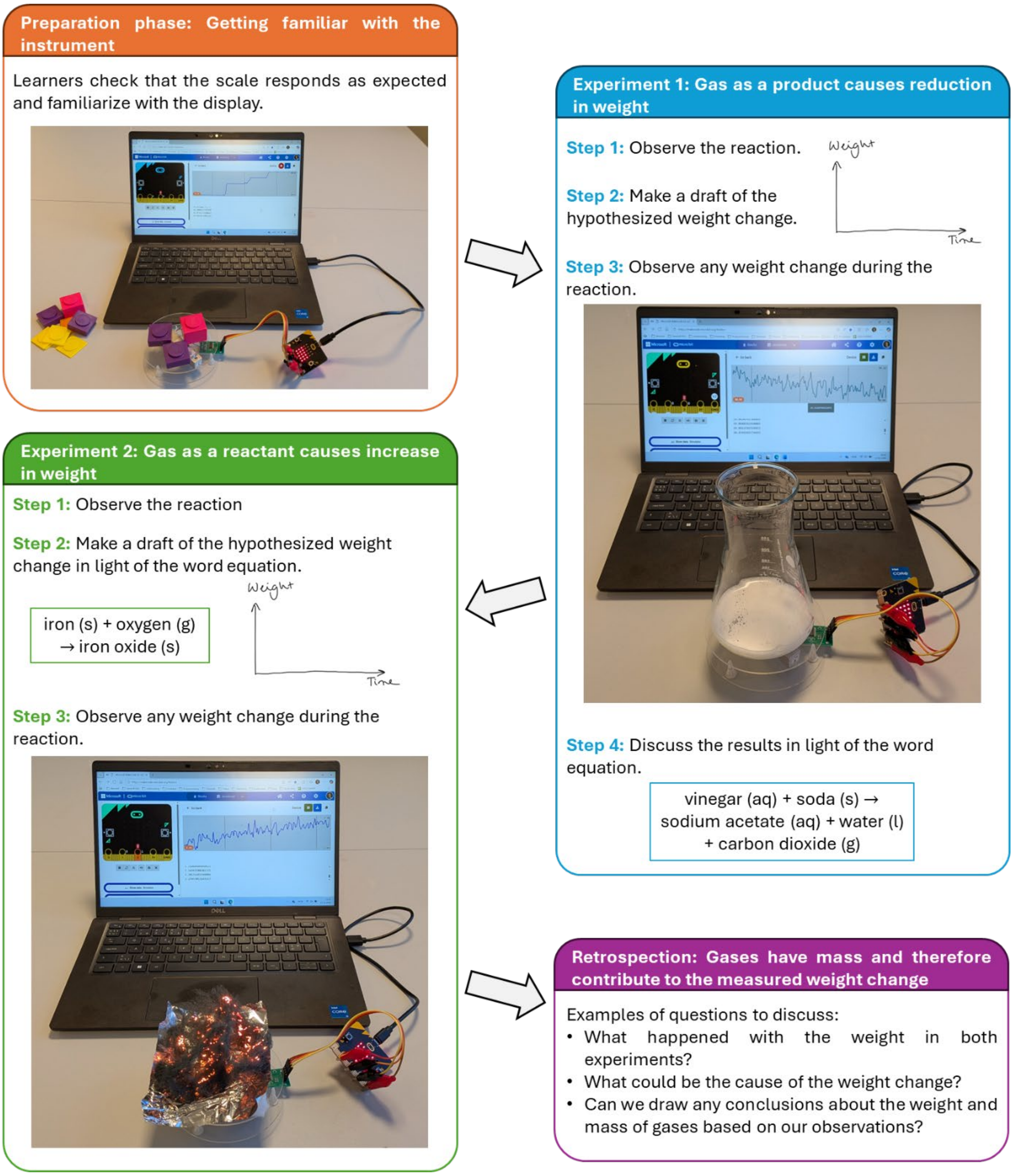
The weight change process in the experiment in this study is invisible to the naked eye and therefore needed to be observed indirectly, by use of an instrument (Kraus, 2024, p. 1054). Observations in general can be qualitative or quantitative of nature, or somewhere in between (Kraus, 2024). On the qualitative side, measurement is dichotomic, which means that a property change is either there or not. On the quantitative side, measurement is mapped on an ordinal or metric scale, reflecting to what degree the change is present. The scale used here is quantitative in the sense that a number is shown on the screen and that the weight graph is shown in a graph with axes. However, the shape of the displayed graph is qualitative.

Trust in the instrument is important for observation (Kraus, 2024). How an observer interprets data from an instrument depends on how the data are represented by the instrument (Kraus, 2024, p. 1059). We therefore suggest that how the data are represented by the instrument affects the trust the observer has in the instrument. Digital devices are often considered more trustworthy than those relying on human senses (Kraus, 2024). Our setup (see Figure 1) was a hybrid: the loading of the scale is analogous and can be manipulated and played with using human senses, whilst the conversion to a digital signal before entering the micro:bit makes it digital.

Digital, as contrasted to analogue devices, cannot show rates of change – the rate of change becomes "invisible and elude observation" (Kraus, 2024, p. 1061). Direct translation to a graphical interface is therefore useful. For time-varying phenomena, such as the processes in this study, reliance on black-box instruments can lead to alienation from the phenomena themselves, unless a direct conversion to graphical representation is possible (Kraus, 2024). Direct translation to a graphical interface is an advantage of the live weight change observation as opposed to the traditional approach of weighing before and after as humans may percept changes easier in the form of a graph (an image) than in fluctuating numbers. The graphical representation (see Figure

1) might therefore offer a better existence of evidence of weight change in gaseous processes than digital numbers displayed on regular scales.

There are several possibilities of how to collect and represent data with micro:bit (e.g. Smevik et al. (2024)). We decided to let students observe the graph “live”, with the purpose to promote students to relate changes observed in the process to changes in the graph while also observing the change, see Figure 1, step 3 in experiment 1 and 2.



Preparation phase: Getting familiar with the instrument

Learners check that the scale responds as expected and familiarize with the display.

Experiment 1: Gas as a product causes reduction in weight

Step 1: Observe the reaction.

Step 2: Make a draft of the hypothesized weight change.

Step 3: Observe any weight change during the reaction.

Step 4: Discuss the results in light of the word equation.

vinegar (aq) + soda (s) → sodium acetate (aq) + water (l) + carbon dioxide (g)

Experiment 2: Gas as a reactant causes increase in weight

Step 1: Observe the reaction

Step 2: Make a draft of the hypothesized weight change in light of the word equation.

iron (s) + oxygen (g) → iron oxide (s)

Step 3: Observe any weight change during the reaction.

Retrospection: Gases have mass and therefore contribute to the measured weight change

Examples of questions to discuss:

- What happened with the weight in both experiments?
- What could be the cause of the weight change?
- Can we draw any conclusions about the weight and mass of gases based on our observations?

Figure 1. *Schematic view of the teaching unit. Protocols for the different elements are given in Table 1.*

Table 1. *Protocols for different elements used in the teaching unit. Please note that the word equation was provided after the live weighing in the soda-vinegar reaction, whilst in the steel wool combustion reaction the word equation was provided before the drawing, to scaffold the educated guess about weight changes during the process.*

Experimental protocol, soda-vinegar reaction	Experimental protocol, steel wool combustion	Co-drawing protocol
Prompt: Observe what happens when mixing 35 ml vinegar (7 vol%) with 3.5 g soda. What do you notice? vinegar (aq) + soda (s) → sodium acetate (aq) + water (l) + carbon dioxide (g)	Prompt: What do you think will happen to the weight during this reaction? iron (s) + oxygen (g) → iron oxide (s)	Prompt: If you did this reaction on a scale, what do you think will happen to the weight? The one holding the marker is not allowed to decide what to draw. Please discuss.
Equipment: • Vinegar (7 vol%, no hazard classification) • Soda (no hazard classification) • Measuring cylinder • Teaspoon • Erlenmeyer flask.	Equipment: • Approximately 2 g steel wool • 4.5 V battery • Crucible tongs • Crucible.	Drawing frame: 
Safety: None of the chemicals are hazardous.	Safety: Open flame, perform experiment on a fire-proof surface and put away long hair.	Drawing materials: • Classroom whiteboard with drawing frame • Non-permanent black marker

Familiarity with the instrument's representation, in this case a graph, is essential for perceiving the data (Kraus, 2024). To understand graphs, and particularly their relationship with a situation, is difficult for many learners (Hinna et al., 2011, pp. 378–379). To support students' familiarity with the graphical representation of the scale we let them investigate the scale using their hands and various gram weights before the experiment started (Figure 1, upper right). As letting the instrument prove itself to users increases trust, playing with the weight before the experiment was also important to support trust in the instrument.

In addition to familiarity with the representations, learners need sufficient knowledge of what to look for to distinguish the weight change process from "the background noise of sensory impressions" (Kraus, 2024, p. 1038). To support both familiarity with the representations and the activation of prior knowledge we therefore chose to let students construct a line graph of what they expected would happen with the weight over time before using the live scale (Table 1, third column). Drawing restrictions and scaffolds together with vertical boards with erasable markers were important here, as will be described in the following.

2.3 Using line drawing to direct learners' attention towards rate of change

Line drawing served two purposes: in addition to familiarizing the learners with the graphical display of the instrument, it provided a material language to direct attention towards the rate of change. The co-drawing protocol (Table 1, third column) required at least one learner to verbally articulate their hypothesis of what the weight change profile would look like. Based on knowledge of more general teaching strategies, we had learners draw their hypothesis line graph cooperatively on a vertical surface, as cooperating to put a graph up on a vertical surface elicits and commits learners to their hypothesis, and informs the teacher of their thinking (similar to the setup suggested by Liljedahl (2021, p. 67), therefore we borrowed his term “vertical surfaces”).

2.4 Word equations to support representations of chemical processes

Word equations (eq. 1 and 2) were provided as supporting representations of the chemical processes. Word equations with aggregate states are sufficient for qualitative reasoning about weight change in chemical reactions, as (g) only on the right-hand side of the equation indicates gas production and (g) only at the left-hand side indicates gas consumption. We chose word equations over of symbolic (reaction equations) to locate the teaching unit at the macroscopical (as contrast to microscopical or symbolical) level (Johnstone, 1982).

3 Part 2: Does live weighing have the potential to serve as evidence of existence of gases, and if so, how?

3.1 Method

To respond to our research question, we ran our teaching unit (Figure 1) for preservice teachers and conducted observations and audio recordings. The teaching unit was part of a larger STEM unit related to programming in primary science, within an introductory science course. Permission to collect data was obtained from the Norwegian Agency for Shared Services in Education and Research (SIKT) in advance of data collection. Students were informed in advance that participating in the session was mandatory, but that participating in the research project was voluntary. Four students chose to participate in the study and worked together in a group sharing a computer and a set of live scale equipment.

During observation the second author conducted the teaching unit, whilst the first author observed as a participant, meaning that she was present in the background and only spoke if there were questions directed at her. After the unit was concluded, the students were asked to reflect on questions such as: “What have you learned, and what can pupils learn from these experiments?”. The purpose of these questions was to shift the students focus from a learner perspective to a teacher perspective, as they are studying to become teachers.

In the observations we looked for where the learners had their attention and noted hand motions and other perceptible actions deemed relevant during the unit on paper together with time indications. We noted how much time was spent on each element and any comments they made related to comparing the match between the drawn and measured graph.

Students' utterances were recorded. Sound recordings were transcribed by the first and second author in cooperation, and observations were added as written comments to the transcriptions. Audio files were deleted as soon as the transcriptions were complete. Students were given the fictious names Stine, Marie, Hanne and Nils. The first author translated teaching materials and quotes to English.

To search for whether the weight has potential to offer evidence of existence of gases we here provide a summary of our observations and excerpts of student dialogue. In this study we have chosen to limit the dialogue excerpts to the concluding discussion at the end of the teaching unit.

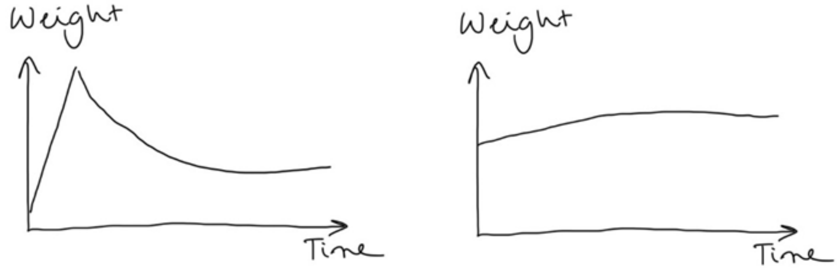


Figure 2. *A re-tracing of students´ line graphs of anticipated weight change in the vinegar and baking soda experiment (left) and combustion of steel wool (right). For the vinegar and baking soda experiment (left) the initial upward slope reflected addition of vinegar. Students anticipated the chemical reaction created a drastic change in weight, most rapidly in the beginning, stabilizing towards the end. For the combustion process (right) students anticipated a slight and linear increase in weight before stabilizing when the combustion, observed as flames, ended.*

3.2 Results from observations

During the vinegar-soda experiment, all learners had their eyes mainly on the Erlenmeyer flask while the reaction took place the first time. Collectively, they agreed on anticipating and drawing a decreasing weight over time graph, with the slope becoming less steep towards the end (see Figure 2 for a re-tracing). When performing the experiment the second time, this time with live weight logging, all had their eyes mainly towards the screen displaying the weight graph. The third time learners divided their attention between the Erlenmeyer flask and the screen. The vinegar-soda part of the teaching unit had a duration of 23 minutes including 3 minutes where the students compared the measured graph to their drawn graph on the board. The reaction itself had a duration of 2-3 minutes. A main challenge (8 out of 23 minutes) was to find out how and when to load the equipment and reactants during the vinegar-soda experiment in a way that the adaptive graph adjusted properly to give readable weight profiles without major disturbances (see Figure 1 for an example). As it is not possible to adjust the limits of the y-axis in the graph manually. The y-axis adapts automatically to the minimum and maximum measurement within the timeframe that is depicted.

The steel wool combustion reaction was unfamiliar to the students. Students repeated the experiment with expressed wonder at the flames spreading across the wool. Unlike the soda-vinegar reaction, where most of the students seemed to have an approximate idea about the rate of weight change, (only) one student had a firm suggestion for the weight change in steel wool combustion. Using the word equation to support her argument, she convinced the rest of the group, and they collectively decided to draw a slightly increasing slope which flattened horizontally towards the end, see Figure 2 for a re-tracing. Also here, students mainly had their attention towards the live graph at the first run with instrument and then divided their attention between the graph and the phenomenon in the second run. The steel wool combustion part had a duration of 11 minutes, including comments on measured and drawn graph.

A common concern is that when programming enters a teaching unit, much time is spent on practical problems and debugging issues. The students said the programming difficulty was fine. They were already familiar with use of micro:bit sensors and live logging environment. Students connected the weight with provided instructions without trouble and played with it using various gram weights and by pushing on it with their finger whilst watching the weight change on the screen. It should be noted here that keeping the materials in order and working requires preparations by the teacher.

The students completed all drawing tasks without trouble. They hesitated to start in the first drawing process, but not in the later ones. Erasable markers let the students negotiate and re-negotiation the shape of the line (which they did) until they reached agreement (uttered as subtle sounds). Vertical boards had students commit to the drawing as it remained visible on the board during the unit as a reference. In the audio file, we could hear students commenting on whether the observed weight profiles from the instrument fit their drawings.

Table 2. *An excerpt of the conversation between teachers and students where they were discussing the question: "Did the weight add anything for your learning?"*

Students and teacher	Conversation	Quote number
Stine:	*"Maybe something about amount? Or like...it was...we thought it was much more, for example in that with the soda and...."*	1
	[Confirmatory responses from the other students.]	
Nils:	*"One could see* [in the graph] *that it* [the weight change] *was quite little."*	2
Hanne:	*"Yes, it is kind of that things can look large, and one thinks that: Ah, we lose a lot, and then it was really just a little. Because it fizzes so much in the starting, and it looks like it is going to become liquid and then - wow - how little we had left, but then it was not really so much to start out with. So, we got it kind of right in front of us, then."*	3
Teacher 1:	*"Yes."*	4
Marie:	*"Yes, I think it was cool. You could sit and follow it whilst you see it happens there* [points to the Erlenmeyer flask], *then you can see, in a way, how much it actually changes in weight* [points to the screen]. *That I think that was a little cool."*	5

Table 3. *An excerpt of the conversation between teachers and students where they were discussing the question: "What have you learned, and what can pupils learn, from the unit?"*

Students and teachers	Conversation	Quote number
Stine:	*"One can see how long it takes, then ... maybe."*	1
Marie:	*"It is a little cool to combine what you see ... both what, and in a way the number of it. That you see the weight by looking at* [points to the graph]. *Yes."*	2
Stine:	*"One might get a bit curious, and then you have to look ... or, at least I did."*	3
Marie:	*"Mmmm."*	4
Nils:	*"And then you learn some about weight, then. Or like* [indecipherable]. *I don't know."*	5
Hanne:	*"Yes, in a way that they mix and get heavier. That it does not go away, kind of. Or like ... that you burn things and get less. One gets more, kind of."*	6
	[Teacher 1 asks Hanne to repeat their statement.]	
Hanne:	*"When they combine, in a way, that it becomes more weight. We usually think that when we burn something there becomes less weight. That they lose something, when it burns up. This one became ... more."*	7
Teacher 2:	*"But this is a pretty weird combustion reaction."*	8
Marie:	*"Mm."*	9
Hanne:	*"Yes, that it is kind of possible."*	10
Teacher 1:	*"Absolutely. What did you say, Nils?"*	11
Nils:	*"No, it was just a bit of the same, just that one... different, must fizz ... or like: Then the gas goes up, and then it gets lighter* [refers back to the soda-vinegar reaction]*, but here* [steel wool combustion] *it is kind of left on top of it and then it becomes more. Or weighs more."*	12

3.3 Results from excerpts of student dialogue

The preservice teachers on several occasions expressed wonder and excitement when describing weight changes they had observed during the experiments. Stine (with others confirmatory) and Hanne (Table 2, quotes 1 and 3) expressed their surprise at the small weight change of just a few grams, as opposed to their anticipated approximate halving of the weight (see Figure 2, left). Marie (Table 2, quote 5) said she thought following the graphical change while being able to observe the experiment was "cool". Hanne and Nils (Table 3, quotes 6 and 12) mentioned they learned (and pupils may learn) that it is possible to burn things and see increased weight. In Table 3 (quote 3), Stine explicitly said, after Marie said something about the weight graph, that they got curious and had to look. In Table 4 (quote 5), Hanne expressed "wow" related to observing things happen in the experiment and simultaneously in the weight graph. Taken together with the observations, we propose these findings indicate that learners classified the weight change process as something remarkable and that they displayed situational interest, which indicated that students consciously perceived it.

Table 4. *An excerpt of the conversation between teachers and students where they were discussing the question: "Was this [using a live weight measurement] worth it?"*

Students and teacher	*Conversation*	Quote number
Hanne:	*"One may consider kind of that, if one had had one such normal scale, and measured in a way right before and right after, I feel it is maybe not as trustworthy as if one keeps track of it all the way* [points to the screen]. *Then one sees what actually happens, instead of one maybe not really knowing."*	1
Stine:	*"How long time."*	2
Teacher 1:	*“Yes.”*	
Marie:	*"I thought like this that if one decides on a scale in the first place, then I find it cooler to have such a live log than having before and after. If one, then, in the first place, decides to measure the way we did now."*	3
Stine:	*Then one also sees when it actually stops, like - yes, okay, now I can take it off* [learner is likely referring to taking the Erlenmeyer flask off the scale]*."* [Stine gestures into the air] [Confirmatory responses from the other students, Marie looks at the screen].	4
Hanne:	*"And then one can start and stop it, such that one, and such pause, so that one sees: wow, now something happened, and then it goes flat like that."* [Hanne points to the screen, indicates a graph with their finger].	5

Table 5. *An excerpt of the conversation between teachers and students where they were discussing the question: Would just numbers would be enough, or did the graph add something more?*

Students	Conversation	Quote number
Hanne:	*"It becomes more visual, then."*	1
Stine:	*"It is maybe easier to understand how fast and how much."* [Stine gestures a graph with her hands.]	2
Hanne:	*"It kind of supports the numbers a bit more, with a graph."*	3

3.4 Evidence of existence of gases

In the excerpt displayed in Table 3, Hanne, who is not much outspoken during the co-drawing of the hypothesis line graph, expresses her surprise that she observed a weight increase during a combustion reaction (Table 3, quotes 6 and 7). Hanne’s statement resembles the very same cognitive conflict Barke (2009, pp. 48–49) suggested to show to illustrate gas has mass: the observation that the weight increases during the process, although it is a combustion, gives evidence of gases having mass. Nils (Table 3, quote 12) compares the two processes. He says that in the vinegar-soda reaction the gas goes up, and it gets lighter, whilst in the steel wool combustion it (the gas) is left on top (combines with the steel wool) and weighs more. Replicates of learner drawings (Figure 2) also indicate attention towards the weight change. Taken together, we claim that learners did notice that the weight went down when gas was a reactant and that the weight went up when gas was a product (Table 3, quotes 6, 7, 12) and that the gas did not disappear, (it was “left on top”; Table 3, quote 12), thus that for these learners, the live scale acted as evidence of existence of gas.

We also show an excerpt (Table 5) where Stine (quote 2) gestures a graph to illustrate their statement about how fast and how much and Hanne (Table 5, quote 3) states numbers are supported with a graph. This gives indications that for these learners, the direct translation to a graphical interface was of importance to perceive the weight change.

4 Discussion

The aim of the teaching unit was to offer the weight as potential evidence of existence of gases. Important factors were trust in and familiarity with the new instrument, as well as *conscious perception*. Just seeing something is not sufficient to be an observation; "[o]nly the classification of an object or phenomenon as something remarkable, which goes beyond the pure visual process, transforms what is seen into a conscious perception" (Kraus, 2024, p. 1038). A factor that can stimulate conscious perception is situational interest, "which must be aroused to prevent the information from being lost in the background noise of sensory impressions" (Kraus, 2024, p. 1038). The learners in this study expressed several emotional responses to being able to observe the weight change during the experiments, such as curiosity and excitement, indicating situational interest and thereby conscious perception.

The direct translation to a graphical representation was appreciated by the learners. Hanne said the graph "supported the numbers" and that the graph became more visual (Table 5, quotes 1 and 3) and that an instrument that showed only before and after was not as trustworthy as "if one keeps track of it all the way [points to the screen]" (Table 4, quote 1), indicating trust in the instrument (Kraus, 2024). How data are represented by an instrument influence how the observer interprets them (Kraus, 2024, p. 1059), particularly in an educational context (Kraus, 2024, p. 1060) and for time-varying phenomena (Kraus, 2024, p. 1061). This can have implications for choice of display in instruments used in STEM teaching.

A threat to trust is alienation. Kraus (2024) warns against black-box instruments, as the functioning of the instrument is important to appreciate the measurements and black-box can result in alienation from the phenomenon itself. Students gladly played with the instrument with their hands and the excerpts do not indicate alienation, rather the opposite, e.g. that they got curious and had to look (Table 3, quote 3), to see what actually happened (Table 4, quote 1). This implies the scale can have potential for STEM learners.

The absence of automated data collection alternates the role of the observer in a way that affects their attention (Kraus, 2024). We believe live data collection was crucial for students' perception of the change process and that the excerpts show evidence of students relating the data during collection to the phenomenon during its course (e.g. Table 3, quote 3, Stine: "One might get a bit curious, and then you have to look... or, at least I did." and Table 2, quote 5, Marie: "You could sit and follow it whilst you see it happens there [points to the Erlenmeyer flask], then you can see, in a way, how much it actually changes in weight [points to the screen]”). When data collection is automated, there is no imperative to pay close attention to the graph and the phenomenon whilst it is unfolding - one can always re-visit it later. The incentive to invest conscious perception in the weight profile, and its connection to the phenomenon, is smaller. “At the fundamental level, conscious perception of a phenomenon and mental activity are necessary conditions for observation" (Kraus, 2024, p. 1063). This suggests live (in contrast to logged) measurements support conscious perception of the weight change. This indication has implications for introducing learners to new instruments, which is important for STEM teaching at all levels.

According to their pre-drawn graphs, learners generally expected a profile like the measured weight changes during the process. But still, they expressed surprise and wonder when confronted with the result, as also reported in Mayer (2011). This indicates a learning value of experiencing also presumably theoretically known phenomena and highlights the importance of the hypothesis co-drawing of a line graph.

We therefore argue that two supporting factors were important for the teaching unit; hypothesis co-drawing of a line graph and live rather than logging data presentation. Hypothesis co-drawing of a line graph familiarized students with the graphical representation of the instrument, provided them with a material language to express their hypothesized change and enabled them to distinguish the observation from other noise. Live rather than logging prevented separation in time and space which often results in alienation from the phenomenon: to observe change, live measurement of change whilst it happens is beneficial. Live rather than log appeared to be important for the learners to trust the instrument.

Regarding misconceptions about gases, learners explicitly stated after the practical that the gases did not disappear (indicates that they do not hold the misconception in Allen (2020)), yet we did not map their preconceptions in this study so we cannot tell whether this knowledge was obtained during the unit. The lack of mapping of preconceptions is a weakness of the study. A way to investigate preconceptions could be to have learners discuss before the practical what happens to gases as they are consumed or produced and relate these phenomena to weight. A careful wording of the discussion question is important, using the cited literature could be a place to start.

Although learners noticed the weight change, this does not imply they understood mass conservation. To achieve the latter, students would in addition need to connect the weight observations to that gases have mass (a theoretical quantity), and that the scale shows a weight change due to the addition or subtraction of these molecules, and thereby mass, to the liquid or solid positioned on the scale (conservation of mass). As a first approach to accomplish this, we could have challenged the learners to discuss in more detail *why* the weight change occurred, asking them to incorporate their understandings of mass and conservation of mass.

In this work we chose a macroscopical perspective. In all the audio recordings we found no reference to the microscopical level. It could be interesting to alter the design to invite learners to connect the macrolevel measurements by the scale with the microscopical level.

5 Conclusions

In this study we explored whether and how live weighing could serve as evidence of existence of gases, and how such live weighing could be integrated into a chemistry teaching unit. To do so, we designed and conducted a teaching unit where pre-service teachers used live weighing to observe weight change in chemical reactions in which gases were produced or consumed.

Taken together, the transcriptions of sound recordings and the observations indicate that learners trusted the instrument. Furthermore, the transcriptions and observations indicate that live weighing can lead to conscious perception of the rate of change in weight and thus assist as evidence of existence for gases. In contrast to earlier approaches involving weighing before and after, our approach invites students to observe the weight while the process evolves and to observe the *rate of change* closely. This is an alternative to the earlier suggested way of first emphasising gas has mass, which is a purely theoretical notion. In our approach, the learner can use live weighing to observe how production or consumption of gases alter the weight during a process and use this observation as a starting point for further theoretical investigations.

We suggested that two supporting factors were important for the teaching unit; hypothesis co-drawing of a line graph and live rather than logging data presentation.

We found indications that there is an important distinction between live and automated data logging with respect to the amount of attention the observer invests. Observations depend on conscious perception, which is supported by live measurements.

The results of this study are promising in terms of the live scale as evidence of existence of gases. We would like to investigate other physical and chemical processes, such as evaporation.

Limitations

The study was of exploratory nature, involving very few participants. Its results are therefore not generalizable. Further work is required to investigate whether learners in general take the scale as evidence of existence. It could also be interesting to study learners at different levels.

Acknowledgements

We thank our colleagues Torunn Smevik, Arne Stormo and Ellen Marie Andersson in our research group “Programming and teaching” for joint developmental efforts of teaching units including various micro:bit sensors.

References

Allen, M. (2020). *Misconceptions in primary science* (Third Edition. ed.). Open University Press.

Azizoğlu, N., & Geban, Ö. (2004). Students' Preconceptions and Misconceptions About Gases [Students' Preconceptions and Misconceptions About Gases]. *Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *6*(1), 73–78. https://izlik.org/JA92XA66XZ

Barke, H.-D. (2009). Misconceptions in Chemistry: Addressing Perceptions in Chemical Education (1st ed.). Springer.

Basheer, A., Kortam, N., Zahran, N., Hofestein, A., & Hugerat, M. (2018). Misconceptions among middle school students regarding the conservation of mass during combustion. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(7), 3109–3122. https://doi.org/10.29333/ejmste/91664

Çetin, P. S., Kaya, E., & Geban, Ö. (2009). Facilitating Conceptual Change in Gases Concepts. *Journal of science education and technology*, *18*(2), 130–137. https://doi.org/10.1007/s10956-008-9138-y

Driver, R. (1994). Making sense of secondary science: Research into children's ideas. Routledge.

Hinna, K., Rinvold, R. A., & Gustavsen, T. S. (2011). *QED 5-10 : matematikk for grunnskolelærerutdanningen : B. 1* (Vol. B. 1). Høyskoleforl.

Johnstone, A. H. (1982). Macro and microchemistry. *Chemistry in Britain*, *18*(6), 409–410.

Kind, V. (2004). Beyond appearances: Students' misconceptions about basic chemical ideas. In: London: Royal Society of Chemistry.

Kraus, S. F. (2024). The Method of Observation in Science Education: Characteristic Dimensions from an Educational Perspective. *Science & Education*, *33*(4), 1033–1068. https://doi.org/10.1007/s11191-023-00422-x

Liljedahl, P. (2021). Building thinking classrooms in mathematics, grades K-12 : 14 teaching practices for enhancing learning (1 ed.). Thousand Oaks, California: Corwin.

Mas, C. J. F., Perez, J. H., & Harris, H. H. (1987). Parallels between adolescents' conception of gases and the history of chemistry. *Journal of Chemical Education*, *64*(7), 616. https://doi.org/10.1021/ed064p616

Mayer, K. (2011). Addressing Students' Misconceptions about Gases, Mass, and Composition. *Journal of Chemical Education*, *88*(1), 111–115. https://doi.org/10.1021/ed1005085

Rossing, N. K., Romijn, E. I., & Smevik, T. (2024). Del I – Lag en enkel elektronisk vekt. *Fra Fysikkens Verden*, *4*, 118–124. https://www.norskfysisk.no/filer/FFV/2024/FFV-indeks2024.pdf

Smevik, T., Stormo, A., & Romijn, E. I. (2024). Logging med micro: bit, en måte å integrere programmering i naturfag. *Læring om læring*, *11*(1). https://www.ntnu.no/ojs/index.php/lol/article/view/5901

Smith, C. L., Wiser, M., Anderson, C. W., & Krajcik, J. (2006). FOCUS ARTICLE: Implications of Research on Children's Learning for Standards and Assessment: A Proposed Learning Progression for Matter and the Atomic-Molecular Theory. *Measurement: Interdisciplinary Research and Perspectives*, *4*(1-2), 1–98. https://doi.org/10.1080/15366367.2006.9678570

Stavy, R. (1990). Children's conception of changes in the state of matter: From liquid (or solid) to gas. *Journal of Research in Science Teaching*, *27*(3), 247–266. https://doi.org/10.1002/tea.3660270308

super:bit. (2025). *Utstyr til super:bit.* https://superbit.no/utstyr-til-superbit/

Time, J. J., Vik, C. B., & Rossing, N. K. (2026). Hvordan vet vi om en hjemmelaget Micro:bit-vekt er god nok for kjemiklasserommet? *Kjemi* (2), 20–26. https://www.kjemidigital.no/dm/2-2026/20/

Vinnervik, P., & Bungum, B. (2022). Computational thinking as part of compulsory education: How is it represented in Swedish and Norwegian curricula? *Nordina: Nordic studies in science education*, *18*(3), 384–400. https://doi.org/10.5617/nordina.9296