Assessment of Student Work Assignment

Final Project for EDF 6237: Principles of Learning and Introduction to Assessment

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Part A: Unit Plan Analysis

The unit plan used for this ASW Assignment, sourced from the American Association of Chemistry Teachers (AACT), explores an important chemical concept: the laws governing the behaviors of ideal gases (2017). The content of this unit meets a wide breadth of the learning standards requirements set forth by the state of Florida (CPalms, 2017). The unit emphasizes inquiry-based student exploration with minimal passive lecture time and several other student-focused strategies influenced by several popular learning frameworks including information-processing theory (Martinez, 2009), Piaget's cognitive constructivism (Woolfolk, 2013), and Vygotsky's social constructivism (Woolfolk, 2013). The complete multi-day lesson plan can be found at https://goo.gl/dgHUAW, which includes some of my own annotations.

Learning Strategies

The role of the teacher in this unit is one of a cognitive apprentice, acting as a cooperative partner in the learning process through strategies of "modeling, assisted performance, scaffolding, coaching, and feedback" (Annenberg Learner, n.d.). The formal curriculum content is introduced through simple videos and brief lectures, which is then supported by classroom discussion, open-ended worksheet questions, demonstrations, student-guided simulations, and labs. In this lesson progression, understanding and mastery of concepts is thus achieved by both social and personal cognitive construction, as students are led through a series of multi-modal learning activities. Retention and transfer of knowledge is supported by creative problem solving, vertical transfer and application of knowledge to authentic scenarios (Ormrod, 2012).

Learning Objectives

The formal learning objectives introduced in the unit focus primarily on Boyle's Law, Charles' Law, Avogadro's Law, and Gay-Lussac's Law, which all contribute to the widely-applicable Ideal Gas Law formula. These laws cumulatively address the relationships between volume, pressure, temperature, and amount of substance in idealized gaseous systems (American Association of Chemistry Teachers [AACT], 2017). Conceptual mastery of these concepts enables the student to envision a variety of gas-based chemical scenarios and solve a number of problems on any standardized assessment.

Each lesson in the unit is followed by analysis questions, ensuring that the teacher is made aware of the student's progress in grasping the concepts therein. The daily nature of these informal assessments provides continuous monitoring of student progress, a valuable tool which the teacher can use to adjust or target instruction (Taylor & Nolen, 2008-a). By the end of the unit, students connect their newly-acquired understanding of gas behavior to mole ratio and stoichiometry, taught earlier in the school year.

Many of the lessons in this unit heavily emphasize components which follow constructivist recommendations. Demonstrations are followed by group discussion, computer simulations are performed in small groups, and students work collaboratively in hands-on laboratory experiments. These are all situations in which individual knowledge is constructed in the context of a community of learning (Woolfolk, 2013). Information is presented in a variety of contexts, using varied models, and at each stage students are given opportunities to make (or revise) their conclusions about the relationships between volume, pressure, temperature, and quantity in gaseous environments. In developing their knowledge in this active way, it is the intention that students come to feel ownership over their learning experience (Woolfolk, 2013).

In order to cement students' learning experiences past their situational classroom "community of practice" (Woolfolk, 2013, p. 175) and move them beyond cognitive apprenticeship (where the student is a learning apprentice to the teacher), the culminating project elevates students towards independent expertise. While the earlier lessons emphasize mastery of the specific details of the gas laws, later lessons integrate these specific concepts into increasingly abstract questions which require creative problem-solving and recall of concepts learned earlier in this and other units. The final assessment project challenges the students' ability to apply their accumulated learning in an authentic, mildly competitive project.

Assessment and Progression towards Mastery

According to the constructivist theory, learning is best internalized when "embed[ed] in complex, realistic, and relevant learning environments" (Woolfolk, 2013, p. 176). Students in this unit move from a general, communal understanding, into smaller, more independent groups working creatively to solve a problem. Many of these problem-solving activities are themselves forms of progressive or summative assessments. For example, the culminating assessment is also a project that asks students to apply their learning to create their own airbag. There are authentic and individual aspects to this project, because students must construct their personal airbag well enough to protect their "passenger" (an egg) to survive a crash test in a self-constructed model "vehicle."

Through this progression from abstract to specific, and from synthetic to authentic, the students fully internalize their learning. Fully internalized learning is also transferrable learning; having students apply knowledge to ill-defined problems, practice vertical transfer, and connect their knowledge to other content domains all promote retention of knowledge and positive transfer to situations outside the classroom (Ormrod, 2012).

Many of the assessments in the unit, such as the labs or post-lab questions, may also be formalized and used for student grading. Using integrated assessments of this type that are tied to the instructional experience of the student are excellent ways to ensure that there is no gap between instruction and assessment (Taylor & Nolen, 2008-a). Assessing consistently throughout the unit also allows the instructor to complete the instruction-assessment cycle by "[using] assessment data to assign skills or strategies for [student feedback]." (Taylor & Nolen, 2008-a). It will be obvious from the portfolio of students' work, in the form of completed worksheets and labs, that they have learned the material and have done so in such a way that they can apply it to a wide variety of problems, both on standardized assessments and in real-world settings.

Part B: Assessment Analysis

The assessment being analyzed in this section is the culminating laboratory project for the gas laws unit plan, called “Where Chemistry Saves Lives!: The Air Bag Stoichiometry Project” (AACT, 2017). This assessment (in its original form, edited only for format, not content) can be found at https://goo.gl/1VhSX1 (all content under section label “Culminating Lab/Assessment”), and the student worksheet version at https://goo.gl/BW4Zo2. In part D of this document, this assessment is more fully edited for better alignment with the constructivist and information-processing theories and improved coverage of learning goals. A link to that altered document will be available in that section.

About the Assessment

This is an extended assessment, stretched among one take-home section and two class periods. In each part, students apply their learning from the unit in a different way. Part one (a background/research portion) is completely conceptual and entirely written; it is an independent research exercise where students perform online research about airbags and answer questions based on their discoveries. Research includes both written resources and videos.

Part two (the planning phase) is a traditional laboratory exercise where students are given a procedure and materials with which to make their own versions of air bags using vinegar and baking soda. Through trials, students determine the best ratio of vinegar to baking soda to use for the airbag, and back up their findings with stoichiometric calculations. This step bridges conceptual knowledge with practical and algorithmic application.

In part three (the crash test), students apply their learning through testing their mettle as “air bag makers” by competing to produce the best possible air bag, measured by how well it protects their “passenger,” a raw egg that is dropped from a height in a student-constructed “vehicle.” This final part allows students to exercise their prior learning in an authentic scenario, thereby “anchoring learning goals in the real world” (Taylor & Nolen, 2008-b, p. 357).

Purpose of Assessment

This three-part assessment is an excellent example of integrated learning and assessment. Its purpose is clear; to reinforce and assess student understanding of gas laws and stoichiometric concepts. The eight-page assessment document contains plenty of background information and well-formed questions that guide students to link concepts together. The assessment is structured in a similar way as labs and worksheets earlier in the unit. Thus, students are familiar with the format and would have a clear understanding of what is expected of them.

This structure addresses and avoids the three predominant pitfalls involved in assessment-instruction mismatch. First, it ensures that assessment content matches instruction content (Taylor & Nolen, 2008-a) by integrating the two. Second, students will understand what is expected from them (Taylor & Nolen, 2008-a), since the summative assessment mimics the type of content covered in earlier progressive assessments for which the students would have received grades and feedback. There is also a rubric which can be made available to the students prior to the project to ensure they know the expectations. Third, students will not be asked to apply their knowledge in any deeply unfamiliar or unreasonably challenging ways (Taylor & Nolen, 2008-a). Reasonably high expectations of student work will have been modeled throughout the the unit; so, though the assessment is appropriately rigorous, there is no invalidating shift in difficulty (Taylor & Nolen, 2008-a).

Types of Knowledge, Skills, and Dispositions Assessed

Student knowledge, skills, and dispositions may all be evaluated with this assessment, as recommended by Taylor & Nolen (2008-b). Objective knowledge evaluation is achieved through questions which combine algorithm and analysis, i.e.: “If 65.1 L at STP of N_2 gas are needed to inflate a real air bag to the proper size, how many grams of NaN_3 must be included in the real airbag to generate this amount of N_2?” (AACT, 2017). Skills are assessed, both through lab outcomes and through questions. Some, like “write the balanced chemical equation between acetic acid and sodium bicarbonate” (AACT, 2017) are interpretive questions; this one tests a student’s ability to recognize an acid-base reaction and apply their knowledge to construct a reasonable chemical equation for the reaction. Others, such as “[based on your balanced chemical equation,] what is the mole ratio of acetic acid and sodium bicarbonate?” (AACT, 2017) are inferential, where students must arrive at their answer from a process of reasoning through earlier answers.

Dispositions are determined through student participation, completeness of the questions (which are generally open-ended enough to allow students to choose how much depth to provide in their answers) and lab outcomes, which reflect how carefully the student has applied the principles of the lab to the final activity. If they have been given the grading rubric, students will be well-prepared to apply themselves to the project; the objectives for the assessment are reflective in the document, which is viewable at https://goo.gl/KsanA2 (AACT, 2017). Please note that this is the original rubric that came with the lesson plan; a revised version of this rubric is provided later in Part D.

Validity of Assessment

Overall the assessment is valid, as it meets the validity standards provided in Taylor & Nolen (2008-a), although some improvement could be made. There are six validity standards: “representation and fidelity,” “cognitive demands,” “consistency across assessments,” “alignment with instruction,” “enhancing fairness and minimizing bias,” and “consequences of the interpretation and use of assessment results” (Nolen, 2008-a, p. 338). Because of the importance of these validity standards, each will be discussed individually.

“Representation and fidelity” requires accurate representation of content objectives and standards, in breadth and depth. This assessment absolutely addresses the breadth of concepts in the gas unit, and but could be rebalanced to better reflect the proportion of time spent on certain concepts as opposed to others.

“Cognitive demands” requires an appropriate level of academic rigor in the assessment. The questions are open-ended and so the level of rigor could potentially be adjusted for students at various levels. However, as they are written, the analysis questions reflect appropriate expectations of high-school level chemistry students.

“Consistency across assessments” is difficult to determine without observing actual results; however, this validity standard would be confirmed by comparing the results of the three different portions of the assessment. Each portions requires students to apply their knowledge in different ways; a pattern of inconsistency between the three parts of the assessment would indicate a problem with this validity standard.

“Alignment with instruction” is obvious in that, as previously discussed, the assessment is itself an integrated continuation of the unit lesson plan. In addition, the content of the assessment and the grading rubric itself is clearly linked with learning objectives from the unit lessons. Objectives such as “students will calculate moles from mass” and “students will carry out stoichiometry problems with solid, aqueous, and gaseous states” becomes “planning illustrates an accurate and thorough understanding of stoichiometry concept underlying the prompt.” Thus, it is clear that the assessment is linked to objectives from the course.

“Enhancing fairness and minimizing bias” is uniquely addressed by this assessment by splitting it into three parts that provide a variety of opportunities for students to display their knowledge. For example, a student who has trouble performing research might lost points in part one, but would still be capable of earning points in part three. Also, since students receive a copy of the grading rubric, they will know what is expected of them and be better prepared to focus their energies on the most important parts of the task; and this rubric can easily by modified for students with different needs. One problem I see with this validity standard is that the assessment does attribute some points to outcomes that are not explicitly knowledge-related (i.e., whether or not the student’s egg breaks, which can be an indicator of knowledge, but the student may also have just had a bad break), which is not recommended by Taylor & Nolen (2008-a). To increase alignment with this validity standard, I would adjust the rubric to make the “broken egg” outcome a bonus, and focus the assessment points largely on the questions which directly link to learning objectives.

Lastly, “consequences of the interpretation and use of assessment results” addresses how the assessment and grading affects student disposition. The project-based, authentic nature of the assessment is constructed to encourage student interest. The grading of the assessment, if aligned with the rubric and the validity standards already addressed, should also be fair and unbiased, resulting in students receiving grades that are in line with their effort and expectations.

Improving Alignment with Unit Learning Objectives

One objection to this assessment being labeled “comprehensive,” however, is that it does not require students to discuss details of the ideal gas law, except in one culminating question at the end. This question does not explicitly ask about the laws, but requires knowledge of them to answer the question. Despite this, the assessment is obviously a continuation of the exploration of concepts from the lesson progression, ensuring continuity and avoiding mismatch.

To increase the assessment’s alignment with the unit content, I would replace or rephrase some analysis questions to emphasize ideal gas law concepts, as opposed to focusing so heavily on stoichiometry, which was only addressed later in the unit. Without this adjustment, if this lab is used as a culminating assessment, there is a risk that students might feel that they had wasted some of their classroom time. In order for this to be a fair culminating assessment, the students’ time and effort expended learning the gas laws should be justified through those concepts representing a larger portion of their final assessment grade. This issue could be alleviated by incorporating some more gas laws concepts into the project’s graded questions, or by increasing the grade weight of earlier progressive assessments that did address their learning of the ideal gas laws.

Conclusion

Overall, I found this assessment to be valid, compelling and useful. I think students will be excited at the thought of executing a physical experiment and seeing if they can accomplish the goal of protecting their eggs with their self-constructed “air bags.” The clever incorporation of the assessment with instruction makes it an obvious choice for instructors who are trying to adhere to validity standards: “when students are engaged in authentic work that becomes both a vehicle for instruction and the products or performances that are assessed, many of the mismatches [between learning and assessment] will not occur” (Taylor & Nolen, 2008-a, pp. 322-323). Finally, I think students will understand the project and view it as useful and interesting. If true, then students will be more likely to apply themselves, engage with the material, and retain the learning objectives from this unit.

Part C: Standards and Learning Goals

In this section, a three-day portion of the “Gas Laws Unit” has been selected for more intense discussion and commentary. The learning objectives, associated state standards, learning strategies and motivational methods in the chosen lesson plans are discussed. The educational theories supporting the claims made are included throughout. The fully annotated lesson plan is available at https://goo.gl/jJFnad.

Learning Objectives

As mentioned in Part B, the final assessment focuses heavily on the concepts of moles and stoichiometry, and less on the gas laws themselves, which should be the focus of the unit. The unit objectives provided in the original document also are weak in addressing some important conceptual connections which are required for state standards.

Therefore, I have chosen to annotate and expand upon the portions of the unit plan that focus more heavily on the ideal gas laws and kinetic molecular theory: “[students will learn how] pressure, temperature, volume, and molecular weight affect how particles in a gas behave” and “[students will learn how to] predict the spatial distribution, interaction, and motion of particles in a gas sample as variables are changed” (AACT, 2017, n.p.). I would add the additional objective, “students will learn that kinetic molecular theory offers an explanation for the behavior of gas particles as described by the ideal gas laws.”

State Standards Supported by Identified Learning Objectives

Understanding the relationship between the gas laws and kinetic molecular theory is an important physics connection that most high school students should be able to handle, and explicitly making this connection will help students transfer their learning to other realms of science (Ormrod, 2012). These objectives align with the following Florida state standards: “interpret the behavior of ideal gases in terms of kinetic molecular theory” (SC.912.P.12.10), “explain that a scientific theory is the culmination of many scientific investigations drawing together all the current evidence concerning a substantial range of phenomena; thus, a scientific theory represents the most powerful explanation scientists have to offer” (SC.912.N.3.1), “recognize that theories do not become laws, nor do laws become theories; theories are well supported explanations and laws are well supported descriptions” (SC.912.N.3.4), and “describe the function of models in science, and identify the wide range of models used in science” (SC.912.N.3.5) (CPalms, 2017, n.p.). This last standard is addressed quite well on lesson plan day three (of the annotated lesson plan), where students use a computer simulation to model behaviors of a gaseous system.

Rationale for Choosing Identified Learning Objectives

These three objectives have been identified for this unit for a number of reasons. First, because they are “learning objectives” as opposed to instructional or behavioral objectives. This is true because the objectives “focus on broad statements of skill areas” (Taylor & Nolen, 2008-a, p. 366) and therefore describe what a student will learn, understand and explore in the unit, rather than focusing on what behaviors they will display (behavioral) or what the instructor will be doing (instructional) (Taylor & Nolen, 2008-a).

I find these objectives and their associated standards particularly important because they form students' adult understanding of the nature of science. For example, many people misunderstand the meaning of "theories" and "laws," and how they relate to each other. Without this foundational understanding, these future adults will not understand modern research; despite taking science courses in high school, they may become functionally scientifically illiterate. As students become members of the public and take on impactful careers in medicine, politics, engineering, or public service (just to name a few), it's important they they can understand emerging research. It is believed that students are more likely to retain information that they feel is more likely to be useful in their lives (Ormrod, J. E.,2014), so I'd like to encourage them to consider potential connections in their adult lives.

Some of my most significant alterations to the lesson plan were made to emphasize one of the important overarching objectives in my course: for students to internalize a profound understanding of how scientific knowledge is formed and communicated. Scientific theories and laws is an important component of that objective. According to the information-processing theory of learning, repeating this theme throughout the class in different contexts will help solidify learning through linking to prior knowledge and gradual revision of understanding; each time the theme is repeated, the student will be re-accessing that knowledge and placing it in a new context (Martinez, 2009). Once a student internalizes what laws and theories really are, and categorize them appropriately, they may also retain more details of specific laws and theories: "some ideas are so important that, if understood, they can help make sense of an entire field of study" (Martinez, 2009, p. 160).

Analysis of Lesson Plan Strategies & Connection to Educational Theories

The constructivist philosophy heavily influences this lesson plan, and there is a strong emphasis on inquiry-based learning. There is minimal straightforward lecturing, and the students are led through a series of observations, experiments and activities to instruct their learning. The lesson plan seems to borrow several structures from the “upper level science class” described by Woolfolk: the class begins with a question, students generate ideas, then experiment and revise their thinking (Woolfolk, 2013, p. 180). Although the experiments are not necessarily “authentic” (that is, tied to real problems in the students’ lives), but there are multiple attempts in the lesson plan to connect the content to familiar concepts and experiences.

In the annotated lesson plan, there is also opportunity for reciprocal teaching and peer cooperation. Each day, the instructor models question-asking and/or demonstrations and the students have the opportunity to express their expertise, work in small groups, or complete a lab cooperatively. Students are also given plenty of opportunity to reflect on their own learning and their previous misconceptions. These features are characteristic of cognitive apprenticeship models which are constructivist in nature (Woolfolk, 2013).

Motivational Strategies

The attempts to connect the lesson plan to the students’ lives is a tool, not just for knowledge construction, but also for motivation. Information perceived as irrelevant by students is rarely retained (Ormrod, 2014). By making clear how these concepts play a role in students lives, they are more likely to be motivated to pay attention. These connections are achieved by mixing life-connection questions among content questions, such as, “when have you seen gases used in everyday life?”, and by performing labs using common household items such as water, candles, baking soda, and vinegar.

In another attempt to retain interest, several changes were made to the lesson plan to reduce potential student anxiety, such as removing the lab requiring physical student interaction, and providing students with prior notice about questions they will be asked to answer in front of the class. These measures are intended to reduce opportunities for humiliation or unwanted attention; anxiety about such interactions can be damaging to student engagement and motivation (Ormrod, 2014). Instead, treating students with respect and offering them opportunities to display their mastery of the content encourages engagement and positive associations with participation in the classroom environment (Ormrod, 2014).

Finally, the use of varied and changing modes of learning is meant to avoid monotony. When covering similar content over the course of three days, it’s important to motivation, knowledge construction and information retention to encourage continued attention and interest by offering differing viewpoints from which to explore the concepts (Ormrod, 2014; Martinez, 2009). Over the course of this annotated three-day lesson plan, students participate in a class discussion, watch several videos, observe three different demonstrations, perform one of those demonstrations themselves, and play with a computer simulation. In the lessons following this annotated section, the students begin doing full laboratory experiments themselves.

Conclusion

Through exercising all these strategies and others, it is my hope that I can construct many days of lesson plans that serve my students’ educational goals, both immediate and long-term. The plans should guide the students towards constructivist learning, encourage critical evaluation of the content, promote engagement with the classroom environment, give the students a sense of self-efficacy, and preserve student dignity regardless of ability or background. It is my sincere hope that I have modified the attached lesson plan to accomplish these goals; however, I am certain that time, experience, and the unique requirements of each student I encounter will lead to numerous further modifications in a real classroom setting.

Part D: Revised Assessment

My revision of the summative unit assessment project focuses on three improvements: expanding coverage of the assessment to touch upon all the unit objectives, clarifying the grading rubric, and making general improvements (editing for clarity and replacing out-of-date resource links). These adjustments also increase the assessment's alignment with the six validity standards reviewed in Part B. The revised assessment document can be viewed at https://goo.gl/Lp5iv3.

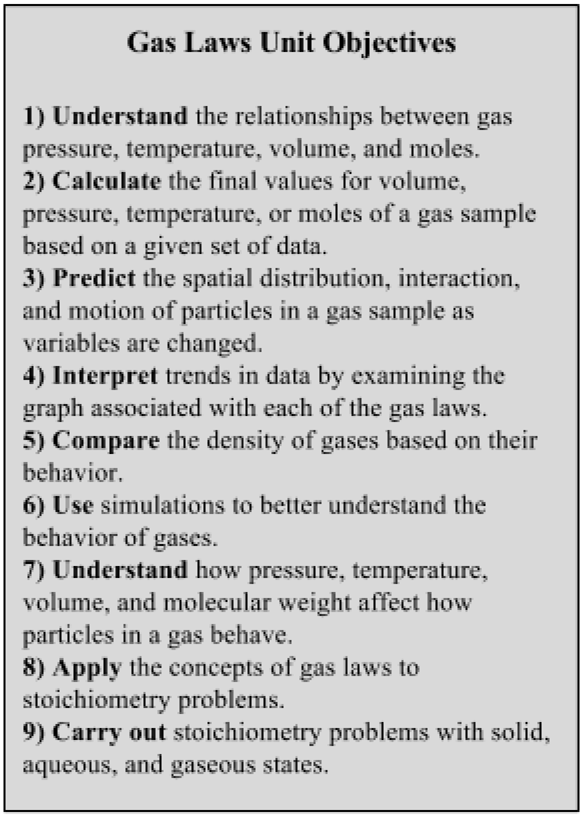
General Improvements

For general improvements, I chose to rework the look of the assignment with different images and to provide students with the objectives and the rubric. I chose to do this to ensure that students completely understand what is expected of them in each section. More on the rubric is addressed later in this discussion. In order to optimize class time and give students more time to review online sources (since we may not have enough internet-enabled devices in the classroom), I made Part 1 an at-home assignment that students turn in.

It was also necessary to replace some of the resource links in Part 1. Both "Airbag Chemistry" and "Car, Airbag, Money: Building an Airbag" from the original assessment were out-of-date links. "Airbag Chemistry" was an important foundational resource for the project, so luckily I was able to recover the content using the "Wayback Machine" website, and I then included it in the text of the project itself. I replaced the fourth source with "Gas Laws Save Lives: The Chemistry Behind Airbags" (https://goo.gl/xE91sf), published by Washington University in

St. Louis, Missouri. I chose to include this link despite the fact that it has content beyond the scope of the course in order to provide students with the opportunity to challenge themselves if they wish to do so. In order to avoid discouraging or confusing students, I made sure to add a note that “some of the content on this page is beyond the scope of this class; don’t worry if you don’t understand all of it!” Finally, I requested that the student provide one resource they found on their own, and explain why they chose it. I did this to encourage students to engage with the content on their own, in the hopes that they will feel more ownership over the research, having done at least a part of it independently.

It is important to note here that, for the sake of inclusivity and in consideration of students who may not have easy access to an internet-enabled device at home, I would give them more than one night to complete part 1, so as to allow them opportunity to visit a library or computer lab. If possible, I would also book after-school extra-help time with access to a few computer stations.



Gas Laws Unit Objectives

1) **Understand** the relationships between gas pressure, temperature, volume, and moles.
2) **Calculate** the final values for volume, pressure, temperature, or moles of a gas sample based on a given set of data.
3) **Predict** the spatial distribution, interaction, and motion of particles in a gas sample as variables are changed.
4) **Interpret** trends in data by examining the graph associated with each of the gas laws.
5) **Compare** the density of gases based on their behavior.
6) **Use** simulations to better understand the behavior of gases.
7) **Understand** how pressure, temperature, volume, and molecular weight affect how particles in a gas behave.
8) **Apply** the concepts of gas laws to stoichiometry problems.
9) **Carry out** stoichiometry problems with solid, aqueous, and gaseous states.

Figure 1: Unit Objectives Overview.

Alignment with Objectives

This unit has nine main objectives, which are displayed in Figure 1. In its original form, the assessment adequately addressed 2, 3, 6, and 8. Most of the connection with the ideal gas law occurs in the “Final Question” in part 3;

enhancing this question allows a more complete assessment of other objectives. One simple fix was for objective 9: this objective is actually covered in the final question, as the reaction does indeed involve a change from a solid reactant to solid and gaseous products. I made this connection more explicit by making a simple addition. I added to the question, “What is happening in this reaction? Please rewrite the complete, balanced equation, including the states of matter for all reactants and products. Is this a chemical or physical change? How do you know?” This allows the instructor to assess if the students understand that there is a phase change occurring during this chemical reaction, and connect it with a concept earlier in the unit: that chemical changes result in a change in the chemical structure of a substance, meaning one substance turns into another; in this case, solid sodium azide decomposes into elemental sodium and nitrogen gas.

After the conclusion question, I added a few more of my own. One of these is, “Consider a closed container. Inside, a reaction occurs in which a solid reactant yields a gaseous product. Consider that this reaction does not go to completion; after some time, both the solid and gas exist in an equilibrium. Does the presence of the solid affect the behavior of the gas in any way?” The answer to this is that the presence of solids or liquids will not affect the gas; only other gases are considered. Only gases will affect each other, as described by the ideal gas law and Dalton’s law of partial pressures. These question now adequately assesses objective 9, and contributes to objective 7.

I further added three more questions: “Consider that the container is made smaller. What would happen?”; “Consider that the container is heated. What would happen?” and “Consider that another gas is added to the container. What would happen?”. These questions address Boyle’s

Law, Charles's Law, and Avogadro's law, respectively. With the addition of these questions, objective 1 and 7 are now adequately addressed.

Objectives 5 and 6 are more difficult in this assessment, so to address these, one of the progressive assessments in the unit (such as the computer simulation in the Part C lesson plan) may need to be followed by a mid-unit quiz with a formal grade, in order to assess student learning of those objectives. I'm afraid that graphical content to this particular assessment would simply make it too unwieldy and overwhelming.

I also added a bonus question: "Suppose you were able to add some moles of a different gas to this closed system. The container is rigid (volume in constant). Somehow, the internal pressure & temperature are also kept stable. What would happen to the system? Why?" This question stretches the students' application of their knowledge; at this point they would have learned all the facts to answer the question, but might not have combined and applied them in this new way. Thus, it is an opportunity for students to gain a few extra points, but it is not a requirement for a good grade. All of these question adjustments and additions contribute to the validity standard "representation and fidelity" (Taylor & Nolen, 2008-a).

Rubric & Grading Improvement

The original assessment grading suggests a 10/40/40 grading split. Since this adds up to 90, I used the remaining 10 points on the additional questions I added at the end of the assessment, but otherwise retained the recommended grading breakdown. Ten points are attributed for the answers to the Part 1 questions (the take-home, research portion). There were originally 11 questions in this section, but I combined two related questions in order to match the questions with the grading; fractional points are confusing for everyone involved and are best avoided if possible.

In Part 2, I was able to attribute 40 points. With 11 questions, I attributed 2 points to each question for a total of 22, in order to emphasize the cognitive aspect of this section, since it is an exploration. The remaining 18 were split among the algorithmic portions: 12 points for the calculations section (2 points per row), and 6 points for the conclusion table (1 point per cell).

Part 3 (the active crash test portion) is graded by rubric, which is available at https://goo.gl/S8NUiG and will be provided to students at the start of the day of the crash test. To see the differences between the revised rubric and the original, you can access the original at https://goo.gl/KsanA2. I made just a few small changes to the document. First of all, I corrected and clarified some wording, as the original rubric had some confusing grammatical errors involving verb tenses. I also reformatted the rubric to make it more visually understandable, and added descriptions to each proficiency level: “Excellent,” “Good,” “Needs Improvement,” and “Doesn’t Meet Expectations.” The original document only assigned point values.

The second change I made to the rubric was in the wording of the “Doesn’t Meet Expectations” portions. The original wording is excessively negative. For example, under “Building the Bag,” the wording is “Carries out practical work with no precision and skill.” I found this to be too discouraging for students and changed it to “Practical work needs significant improvement.”

The third change I made to the rubric was to add another points level. In the original, there are levels for 8, 6, 4 and 2 points. I added a 0 point level which indicates lack of participation or unsafe behavior. My intention in doing this is to highlight to the students that any attempt at participation is better than none (even if answers are incorrect), and also that unsafe lab behavior will result in a significant loss of points , if not removal from the project altogether.

There was another change I had proposed in Part B, in which I criticized the choice to include the fate of the student's egg "passenger" in the grading rubric. However, upon further reflection and review of the rubric, I think it is actually assessed fairly. While other portions of the rubric range between 2 and 8 points (a minimum of 2 provided simply for participation), students receive 8 points for an egg which remains whole, and 6 for an egg that cracks. 8 points is considered "excellent" in the rubric, and 6 is considered "good." Therefore, I think this is fair, and the existence of the egg result in the rubric contributes to the perception that it is indeed an "authentic" experience. Without that, it is not as true a simulation of vehicle airbags, whose only purpose is indeed to ensure the safety of the passenger. Further, if students perform excellently in all other areas of the rubric, they will still receive an "A" grade even if they lose points on the egg; they will not be unduly punished due to unfair grading.

As mentioned previously, the final 10 points are awarded to the conclusion questions. 1 point each is awarded to the shorter questions, and 5 to the longer question requiring calculation and application of the ideal gas law. The bonus question is worth 5 points; not an unfair amount to students who can't answer, but for exceptional students, it is sufficient to cover any casual errors made elsewhere in the assessment.

Conclusion

In conclusion, I believe that the final version of this assessment is both valid and inclusive. Students are provided multiple ways to demonstrate their expertise, in both written format and through their project performance. The free-response nature of the questions allows students of different cognitive levels to answer to their own capacity, and the structure of the project is such that modifications could easily be made for students with IEPs (Taylor & Nolen, 2008-a). The assessment as it stood was acceptably cognitively demanding without being unreasonable. The questions added at the end of the assessment rounded out this validity standard and the bonus question provides an extra challenge to students up to the task. The assessment is balanced and should accurately represent student learning , representing "consistency across assessments" (Taylor & Nolen, 2008-a), and is well-aligned with instruction. The minor adjustments made to the rubric helped "enhance fairness and minimize bias" (Taylor & Nolen, 2008-a) and ensured that the assessment results are fair and based on student knowledge, with minimal points hinging on the results of their experiment.

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