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"Mark it yourself, it's good for you!" A case study examining the impact of self-assessment on student learning and motivation in a year 12 physics class studying energy

James Moore

(PGCE Secondary Science (Physics), 2018-2019)

email: jkmoore898@gmail.com

Abstract

Self-assessment is a complex metacognitive process with widely reported benefits for students in secondary education. This paper explores the impact of self-assessment on the learning and motivation of a year 12 physics class in a Cambridgeshire secondary school over a sequence of lessons covering the topic of energy. The use of self-assessment appeared to benefit students by providing them with timely, insightful feedback and promoting self-reflection and self-regulation, whilst also enabling differentiation and promoting mastery. Incorporating self-assessment in homework emerged as an opportunity for developing future practice and research, in particular using online platforms that enable students to guide their own learning.

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Introduction

In the culture of performativity and accountability that pervades schools internationally, the use of self-assessment offers an opportunity to put learning back in the hands of the learner (Bourke, 2016). This study aims to explore how self-assessment can benefit students' learning and motivation. In secondary school physics, questions can be mathematical or explanatory, but answers are (generally) either right or wrong. This presents an excellent opportunity to exploit the potential benefits of self-assessment and assess its impact. As with any teaching method, the impact of self-assessment is likely to depend on a range of factors, including, but not limited to: the student; the teacher; and the specific resources and activities used to enact it. This study analyses a sequence of lessons covering the topic of energy to a year 12 physics class at a Cambridgeshire secondary school, during which the students were exposed to a variety of self-assessment activities. The aim is to establish the impact of self-assessment on the learning and motivation of these students, as well as the key factors which contribute to the successful implementation of self-assessment. In this report, I present a review of the literature on self-assessment and its links to learning and motivation, before detailing my research design and methodology, then reporting and discussing key findings and offering several messages to inform teaching practice and future research.

Literature review

What is self-assessment?

> "Self-assessment is a process of formative assessment during which students reflect on and evaluate the quality of their work and their learning, judge the degree to which they reflect explicitly stated goals or criteria, identify strengths and weaknesses in their work, and revise accordingly."
>
> (Andrade & Du, 2007, p.160)

Whilst there is no generally accepted definition, Andrade's interpretation of self-assessment offers a fairly comprehensive overview. Self-assessment does not mean simply marking one's own work; it is a process by which students gather information to determine the extent to which their work meets success criteria and derive feedback for improvement. It comprises both an evaluation of quality – self-evaluation – and a more general appreciation of one's strengths and weaknesses, reflecting on one's understanding of a topic – self-reflection. Some interpret self-assessment, primarily, as a response to a task or activity (Boud, 2000; Andrade & Du, 2007; Andrade & Valtcheva, 2009). Bourke (2016), however, challenges this short-term view, advocating that self-assessment should be experienced as an ongoing metacognitive process including students setting their own learning goals: "self-assessment involves the learners focusing on learning, and not just the quality or task criteria to judge an outcome" (p.108). Bourke conceptualises self-assessment as reflective intelligence, which Broadfoot (2000, p.212) defines as "the ability to engage in the metacognitive monitoring of one's own learning that is likely to be the central feature of successful learning in the future". Self-assessment can also include the identification of learning strategies and steps to enhance performance (McMillan & Hearn, 2008). This interpretation of self-assessment as a continuous process closely relates to self-regulation: the continuous process by which learners set themselves goals and monitor their cognition, behaviour and motivation in context (Pintrich, 2000). Broadly then, it seems that self-assessment comprises three elements: evaluating the quality of one's own work; reflecting on one's own strengths and weaknesses; and an ongoing metacognitive monitoring of one's own learning. For the purpose of this report, I refer to these elements as self-evaluation, self-reflection and self-regulation respectively.

While the literature lacks consensus on its definition, it is widely supported that self-assessment offers significant benefits for learning and motivation in secondary school students. Relevant studies include Black and Wiliam's (1998) extensive review of the formative assessment literature; Black and Harrison's (2001) research into the use of self- and peer-assessment by twelve science

teachers across six UK comprehensive schools; and McMillan and Hearn's (2008) review of theoretical and research literature on self-assessment. In the remainder of this section, I explore how self-assessment can impact learning and motivation, and the barriers and enablers to its successful implementation.

How does self-assessment impact learning?

> "Developing learners' ability to self-assess will contribute to an understanding of themselves and their learning in a fundamental way, often not possible through other assessment practices."
>
> (Bourke, 2016, p.108)

Not only is self-assessment "a sine qua non effective learning" (Black & Wiliam, 1998, p.26), it has a unique potential to enhance learning (McMillan & Hearn, 2008; Bourke, 2016). Whilst defining learning itself is a contentious issue, broadly, it concerns changing behaviour due to experience (Gross, 2010) with a view to extending one's capabilities (Howe, 1980). This can include increasing knowledge, memorising, acquiring skills, making sense of ideas, and understanding reality in a different way (Säljö, 1979). As a formative assessment tool, self-assessment helps students understand learning intentions and success criteria, provides formative feedback and makes students active in the learning process, taking ownership of their learning (Black & Harrison, 2004; Wiliam, 2011). Without the delay required for teacher marking, self-assessment also presents an opportunity for immediate feedback, which has been shown to enhance learning, for example in Dihoff, Brosvic, Epstein, and Cook's (2004) empirical studies of 190 undergraduate students. Self-assessment can encourage students to create, apply and challenge success criteria, which helps them understand the link between assessment and learning (Boud, 1995; Torrance, 2007). Regular exposure to self-assessment activities also develops students' self-reflection, self-management and metacognitive skills (Broadfoot, 2000; Assessment Reform Group, 2002; Mock, Lung, Cheng, Cheung, & Ng, 2006), contributing to their ability to self-regulate, which is central to future learning (Pintrich, 2000; Tan, 2007). Thus, self-assessment can deliver a range of benefits for learning. In the short term, it helps clarify task requirements and learning intentions, keeps students active in the learning process and provides them with formative feedback. In the longer term it encourages students to monitor their own learning: self-regulation. In short, self-assessment "empowers students to guide their own learning and internalize the criteria for success" (McMillan & Hearn, 2008, p.40).

Self-assessment also forms an integral part of cognitive and constructivist theories of learning and metacognition (McMillan & Hearn, 2008). In developing knowledge, students must be able to monitor their own learning and thinking. This requires self-assessment before and during the learning process to enable students to construct meaning for themselves by connecting new knowledge, understanding and skills to those they already possess. A self-assessing student can carry out this process independently. Metacognition is closely linked to self-regulation (Pintrich, 2000): it concerns students' ability to "monitor, evaluate, and know what to do to improve performance" (McMillan & Hearn, 2008, p.43). Relevant skills include: "checking understanding, predicting outcomes, planning activities, managing time, and switching to different learning activities" (ibid.). Such skills can positively impact students' achievement and can be taught. Self-assessment can, therefore, be considered both a step inherent to the learning process and an aid for students to advance their learning.

How does self-assessment impact motivation?

> "Self-assessment plays a significant role in developing self-perceptions that lead to greater motivation."
>
> (McMillan & Hearn, 2008, p.44)

Motivation is fundamental for learning (Lindstrøm & Sharma, 2010), and self-assessment has the potential to significantly improve motivation in students. There are several different theories of motivation in education, such as self-determination theory (Ryan & Deci, 2000), self-efficacy theory (Bandura, 1994; Seifert, 2004) and achievement goal theory (or goal-orientation) (Anderman, Austin, & Johnson, 2002). In the recent literature, Lindstrøm and Sharma have conducted research that is particularly relevant to this report, creating two questionnaires to measure goal-orientation (Lindstrøm & Sharma, 2010) and self-efficacy (Lindstrøm & Sharma, 2011) respectively in undergraduate physics students. Notably, they remark that motivation studies can be context specific. Thus, given the applicability of Lindstrøm's questionnaires – which have been trialled and adapted to measure goal-orientation and self-efficacy in *physics* students – to my research, and to enable me to analyse their results in depth, I have chosen to focus on these two areas within the broad field of motivation.

Achievement goal theory concerns students' reasons for engaging in academic tasks (i.e. their goal-orientation), and self-assessment can promote goals which are most conducive to learning. There is a broad distinction between mastery- and performance-oriented students (McMillan & Hearn, 2008;

Lindstrøm & Sharma, 2011). Mastery-oriented students monitor their competence against self-defined standards, focussing on learning and understanding. Such students tend to be intrinsically motivated and self-regulating (Pintrich, 2000). Conversely, performance-oriented students tend to focus on the outcome of the task, measuring their competence relative to others. Mastery goals help students internalise the monitoring and evaluation of learning (McMillan & Hearn, 2008). Self-assessment supports a mastery orientation by enabling students to reflect on their own learning, whereas performance orientation requires external validation of whether successful learning has taken place (e.g. a grade). Work avoidance is an alternative goal orientation, in which students aim to achieve maximum performance through minimum effort (Lindstrøm & Sharma, 2010). Such students may be "bright but bored" (Seifert, 2004, p.146) and as a result take less control over their learning. Some students are cooperation-oriented (Covington, 2000), meaning they value interaction with their peers in the learning process (Lindstrøm & Sharma, 2010). Thus, if a self-assessment focus restricts peer-interaction, this could inhibit motivation for these students. Overall, the goal-orientation of a student can significantly affect their motivation, but encouraging students to self-assess can promote goals which are most conducive to learning. In particular, self-regulation forms an essential link between academic goals and behaviour for learning (Covington, 2000).

Self-efficacy relates to a student's belief that he or she can perform a certain task and is a robust predictor of academic achievement (Bandura, 1994; Lindstrøm & Sharma, 2011). It is closely linked to achievement goal theory. For example, mastery experience (the experience of mastering a task) is a key source of self-efficacy (Bandura, 1997). In physics this might be solving problems of increasing difficulty or understanding and linking together new concepts (Lindstrøm & Sharma, 2011). Seifert (2004) notes that the most successful students have high self-efficacy: they self-regulate and focus on mastery goals, rather than completing tasks for extrinsic rewards. Students who attribute their successes and failures to malleable internal factors (e.g. effort) also tend to be better learners than those who attribute outcomes to fixed factors (e.g. innate ability). The latter are more likely to try and avoid failure than strive for success. This is particularly prevalent in western cultures, where students often tie their self-worth to academic performance. In general, students with higher self-efficacy are more motivated to learn, and self-assessment can support students' self-efficacy: it helps them recognise what they have mastered and what they should focus their efforts on (McMillan & Hearn, 2008). This in turn can support students' learning through enhancing their self-regulation skills (Pintrich, 2000) and reflective intelligence (Bourke, 2016).

What factors influence the implementation of self-assessment?

While self-assessment offers numerous benefits for learning and motivation, relatively little research has been conducted into how it should be designed and implemented to maximise its impact (Harris & Brown, 2013; Wanner & Palmer, 2018). The literature offers some potential barriers and enablers to implementing self-assessment, which relate predominantly to perceptions of self-assessment, the role of the teacher, and the student.

A major challenge in implementing self-assessment is overcoming the mindset that assessment is the responsibility of the teacher; not the student (Harris & Brown, 2013). In countries such as the UK, which operate regular high-stakes summative examinations, students are likely to resist self-assessment, since their experiences of assessment have not encouraged them to value their own opinion of their work. Bourke (2016) advocates self-assessment as a tool to liberate students from entrenched assessment practices. However, it is important that the focus of self-assessment is on learning rather than outcomes, otherwise self-assessment may discipline students rather than empowering them (Tan, 2009), negating the potential for students to take ownership of their learning (Wiliam, 2011). Teachers should therefore emphasise that self-assessment is for learning purposes; not summative judgement (Black & Harrison, 2001). Students may also believe they lack the skill to self-assess (Harris & Brown, 2013). To combat this, students need training in self-assessment so that they can learn how to provide themselves with effective feedback and subsequently use it (Black & Harrison, 2004; Wanner & Palmer, 2018). So, while the perception of the teacher as the sole assessor presents an obstacle to self-assessment, this can be mitigated through creating a culture of self-assessment for learning within the classroom, in which students become familiar with self-assessment as a learning tool.

Although students should take the lead in self-assessing, they require appropriate guidance. When self-assessing, students want well-defined success criteria to enable them to make accurate judgements (Harris & Brown, 2013). The teacher has an important role to play (Wanner & Palmer, 2018). Teachers should convey to students the meaning of quality feedback and how to use it to improve. Seifert (2004) also suggests that if teachers communicate the objectives of the lesson to the students this can enhance their self-efficacy. However, when self-assessed tasks are routinely initiated by the teacher, students may see these tasks as simply another assignment to complete (Bourke, 2016). Indeed, "students taught with a more controlling approach not only lose initiative

but learn less effectively, especially when learning requires conceptual, creative processing" (Ryan & Deci, 2000, p.71). This is particularly pertinent in a conceptual subject such as physics. Therefore, to enable successful self-assessment, teachers must balance guidance and autonomy in the classroom.

The impact of self-assessment can also depend on the individual student, particularly their motivation, ability and perceptions. Mastery-oriented students with higher self-efficacy may be more likely to engage in self-assessed tasks and therefore benefit more from them (Seifert, 2004). Conversely, work-avoiding students with lower self-efficacy may be more motivated by extrinsic goals, thus craving external validation from a grade or their teacher (Lindstrøm & Sharma, 2010). In terms of academic ability, stronger students tend to be better self-assessors; lower attainers are less forthcoming when they lack understanding (Black & Harrison, 2001). Students' perceptions of self-assessment also vary, which can influence its impact. Many students think of self-assessment as simply self-evaluation (Andrade & Du, 2007; Bourke, 2016), neglecting the metacognitive aspects of self-reflection and self-regulation. Only those students with the most sophisticated understanding of self-assessment, who use success criteria to set and monitor their own learning goals, can yield the full benefits from it (Bourke, 2016). Thus, the academically able, mastery-oriented student with high self-efficacy seems best-placed to engage with and benefit from self-assessment. The teacher, therefore, has a responsibility to ensure that all students reap the rewards of self-assessment, providing suitable guidance and extrinsic motivation to those less well-suited to self-assessing.

Summary and research questions

In summary, self-assessment is a complex metacognitive process comprising three elements: self-evaluation; self-reflection; and self-regulation. In the short term, students gain formative feedback from a learning activity through self-evaluation, judging the quality of their work (Andrade & Du, 2007). Subsequently, students self-reflect, identifying their strengths and weaknesses in context (ibid.). This supports the ongoing process of self-regulation, whereby students monitor and guide their own learning (Pintrich, 2000). Self-assessment has the potential to significantly and positively impact learning and motivation. It provides timely formative feedback (Dihoff et al., 2004; Wiliam, 2011), improves students' understanding of what they must do to succeed, and helps them devise and navigate a route to get there (McMillan & Hearn, 2008). It can encourage students to focus on

mastery goals and foster their belief that they can complete tasks: self-efficacy (Lindstrøm & Sharma, 2010, 2011). When implementing self-assessment, however, due consideration must be given to the motivation and capabilities of individual students, their perceptions of self-assessment and the guiding role of the teacher.

My review of the literature leads me to the following research questions:

- RQ1: How does self-assessment impact student learning?
- RQ2: How does self-assessment impact student motivation?
- RQ3: What are the barriers and enablers to the successful implementation of self-assessment?

In the next section, I explain the research design and methodology of this study, detailing how I implemented self-assessment and collected data for each research question.

Research design and methodology

Overview

To gain a robust understanding of self-assessment in relation to the research questions I conducted a case study with both concurrent and pre- and post- data collection (Jensen & Rodgers, 2001). The case under examination is a sequence of lessons in a Cambridgeshire secondary school to a year 12 physics class studying energy. The class contained fifteen male students aged 16 or 17 of mixed ability, with predicted grades ranging from A* to C, including one student with Autism Spectrum Disorder (ASD). Energy, as a topic, presents the opportunity for both mathematical and explanatory challenges, so offers a range of scenarios in which to use and analyse self-assessment.

The topic was taught in 250 minutes (three 50-minute lessons and one 100-minute lesson), followed by an end of topic test and a 50-minute feedback lesson, over a four-week period. Throughout this process, students were exposed to multiple self-assessment activities. An energy concept test and motivation questionnaire were conducted before and after the 250-minute lesson sequence to provide quantitative data on learning and motivation; concurrent qualitative data were collected through teacher observations, my personal reflections and student responses to exit tickets at the end of each lesson. Two student focus groups were conducted after the 250-minute lesson sequence to provide further qualitative data. Figure 1 illustrates the case study timeline, including the self-assessment activities and data collection methods, which I discuss in more detail below.

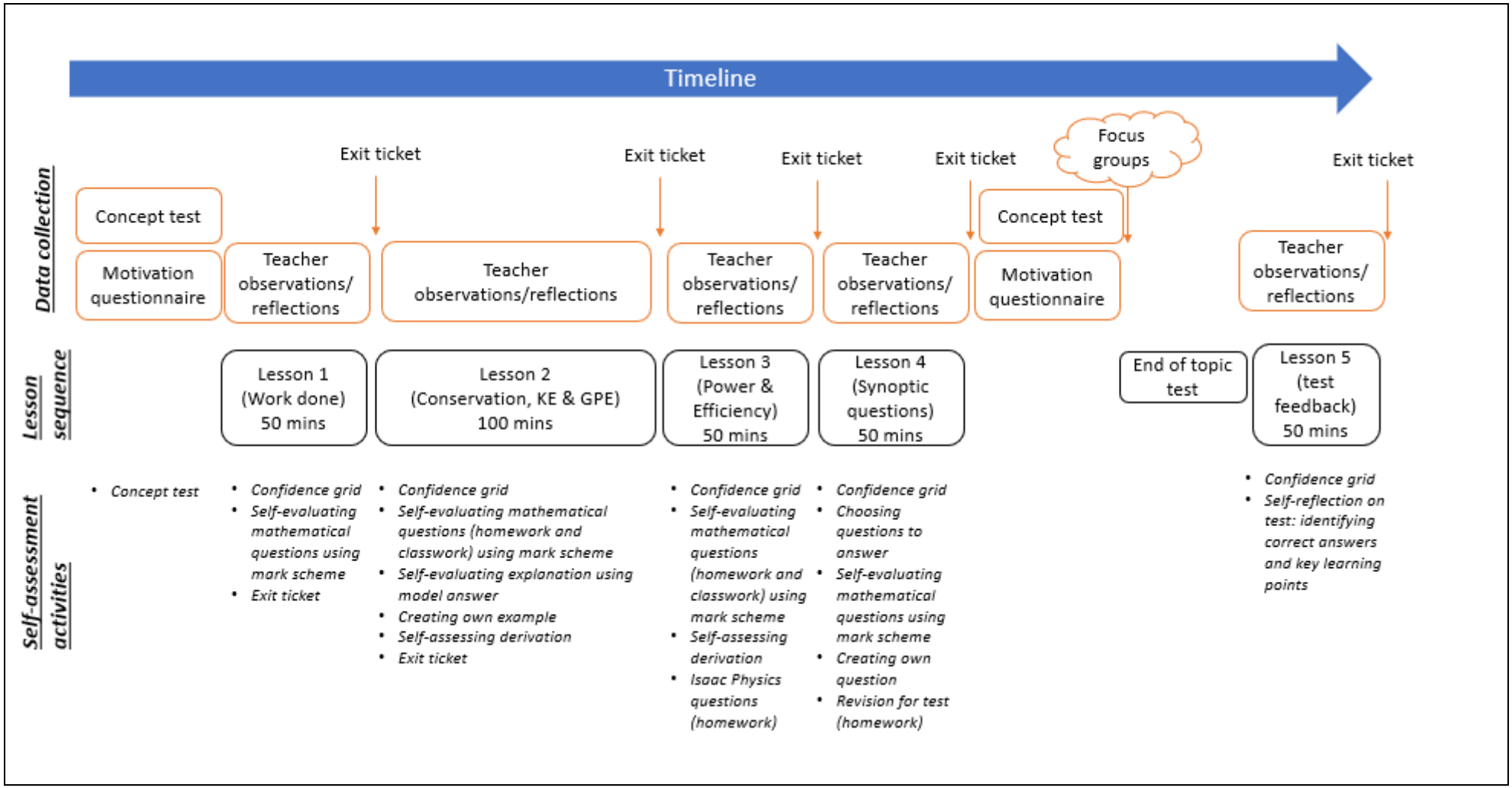

Figure 1: Case study timeline

Self-assessment activities

Students completed a range of self-assessment activities during lessons and for homework (as illustrated in Figure 1). Table 1 details the rationale behind individual activities, but broadly, I selected a variety of tasks to expose students to the entire self-assessment spectrum.

Activity	Rationale
Confidence grid	This contained syllabus points in the OCR A Energy topic (OCR, 2018), with five adjacent boxes for students to shade in to reflect their confidence. Students were asked to update this regularly throughout the lesson sequence. This resource was inspired by "traffic-lighting" as recommended by Black & Harrison (2001) to help students self-reflect and self-regulate.
Self-evaluating questions using mark scheme	This helps familiarise students with success criteria and identify and learn from their mistakes (Black & Harrison, 2001). Both mathematical and explanatory questions were included, since they present different challenges for self-evaluation. Students completed homework with and without access to numerical answers to explore the effect of immediate feedback (Dihoff et al., 2004).
Exit tickets	Whilst these also constitute a data source, exit tickets present an opportunity for student self-reflection (Marzano, 2012; Danley, McCoy, & Weed, 2016). Each exit ticket included a question assessing a key concept taught in that lesson followed by a student self-reflection of confidence in their answer.
Creating own examples/questions	This activity helps students understand the train of thought required to answer questions, rather than relying on recall (Black & Harrison, 2001), as well as enabling them to better understand and interrogate assessment criteria (Torrance, 2007).
Derivations with hints	Students attempted to derive relevant formulae with access to hints which they could choose to use, encouraging them to take ownership of their learning (Black & Harrison, 2004; Wiliam, 2011).
Isaac Physics questions ('Isaac Physics', n.d.)	This online platform was used for homework, providing students with a selection of mathematical questions of varying difficulty. Students could choose the level of question and access hints at their discretion, promoting self-regulation and ownership of learning (Pintrich, 2000; Wiliam, 2011), whilst also receiving immediate right-or-wrong feedback with the opportunity to answer until correct (Dihoff et al., 2004).
Choosing questions	Students were asked to choose from a selection of exam style questions based on their weaknesses. This activity encourages students to self-reflect (Andrade & Du, 2007) and empowers them to guide their learning (McMillan & Hearn, 2008; Wiliam, 2011).
Revision	Revising for their end of topic test presented students an opportunity to self-reflect and self-regulate (Pintrich, 2000; Andrade & Du, 2007).
Test self-reflection	The end of topic test was teacher-marked and students were asked to write their own corrections and identify their key learning takeaways from the test, promoting self-reflection (Andrade & Du, 2007) and helping students identify the next steps to enhance their performance (McMillan & Hearn, 2008).
Pre-topic concept test	Whilst also used for data collection, the pre-topic test on energy concepts provided a self-assessment opportunity by giving pupils an idea of where their work was going (Black & Harrison, 2001).

Table 1: Rationale behind self-assessment activities

Thus, each activity enabled one or more of self-evaluation (e.g. self-marking homework), self-reflection (e.g. stating confidence on answers to exit ticket questions) and self-regulation (e.g. choosing questions to answer based on weaknesses). These aspects of self-assessment addressed by each activity are summarised in Table 2.

Activity	Self-evaluation	Self-reflection	Self-regulation
Confidence grid		✓	✓
Self-evaluating questions using mark scheme	✓		
Exit tickets		✓	
Creating own examples/questions		✓	✓
Derivations with hints			✓
Isaac Physics questions (‘Isaac Physics’, n.d.)	✓	✓	✓
Choosing questions		✓	✓
Revision		✓	✓
Test self-reflection		✓	✓
Pre-topic concept test		✓	✓

Table 2: Aspects of self-assessment in each activity

Data collection methods

The impact of each self-assessment activity was measured concurrently through qualitative data from teacher observations, my own reflections and student responses to exit tickets. Emerging themes were explored further in two focus groups. The qualitative data sources were targeted primarily at identifying barriers and enablers to implementing self-assessment but also offered an insight into the impact on students’ learning and motivation. Quantitative data was collected before and after the 250-minute sequence, including: a diagnostic test assessing key energy concepts, which helped guide teaching and measure learning; and a motivation questionnaire to measure student motivation. Table 3 summarises which of these data sources were used to investigate each research question.

Using multiple data sources for each research question enables triangulation of findings and mitigates against biases in individual data collection methods (Evans, 2013). Furthermore, similar data collection methods to those I have employed have been used in the highly relevant field of self-regulated learning – for example, self-report questionnaires, structured interviews and teacher

judgements (Fraser, 2000) – lending support to the viability of these methods in this context. I provide more detail on each data collection method below.

Research question	Concept test	Motivation questionnaire	Exit tickets	Teacher observations	Lesson reflections	Focus group
1. How does self-assessment impact learning?	✓		✓	✓	✓	✓
2. How does self-assessment impact motivation?		✓	✓	✓	✓	✓
3. What are the barriers and enablers to implementing self-assessment?			✓	✓	✓	✓

Table 3: Data collection methods for each research question

Quantitative methods

Students' learning and motivation were measured using a pre- and post-study concept test and motivation questionnaire respectively. Given the small sample size, data from these methods are only used indicatively, so while results can point towards conclusions, these are not necessarily statistically significant.

Energy concept test

Energy, as a topic in physics, presents both mathematical and explanatory challenges for students, and brings with it numerous misconceptions. I constructed an energy concept test based on common misconceptions identified by the American Association for the Advancement of Science (AAAS, n.d.), using questions from the AAAS inventory and other concept tests in the literature (Thornton & Sokoloff, 1998; Singh & Rosengrant, 2003; Ding, 2007; Engelhardt, Robinson, Price, Smith, & Goldberg, 2018), as well as one final question I wrote myself.

Students completed the test before and after the 250-minute lesson sequence. The pre-test was used to inform teaching during the sequence and as a benchmark to compare with the post-test. The pre-test also enabled student self-assessment by giving pupils an idea of where their learning was headed (Black & Harrison, 2001). Using the same test each time enabled like-for-like comparison in the analysis. However, it is possible that the students, having attempted the same questions in the pre-test, would naturally be more likely to score higher in the post-test, for example because they

might have discussed their answers with each other and come to a common consensus on the correct answers. To mitigate against this, I did not give students solutions to the pre-test, nor did I inform them their marks, and I collected the question papers back in once the pre-test was finished. I also did not tell the students that they would be sitting the same test again, and, as the post-test was sat approximately four weeks after the pre-test, this provided some time for the students to forget the questions.

Motivation questionnaire

A motivation questionnaire was constructed to measure students' goal orientation and self-efficacy, based on the questionnaires developed by Lindstrøm and Sharma (2010, 2011) for physics undergraduates. The original questionnaires are aimed at first year students at US universities, so the wording of several questions was altered slightly to suit a year 12 UK cohort. For example, "I know I can pass the physics exam if I put in enough work during the semester" became "I know I can do well in my physics tests and exams if I put in enough work during the term".

The questionnaire was given to students before and after the 250-minute lesson sequence. The initial responses offered an insight into the goal-orientations and self-efficacy of the students and provided a baseline against which to measure any changes in motivation in the second set of responses. Responses were on a Likert scale, enabling quantitative analysis, with specific questions addressing mastery-orientation, performance-orientation, work-avoidance, cooperation-orientation and self-efficacy.

Qualitative methods

Exit tickets

Exit tickets were used to provide formative assessment data, prompt student self-reflection and acquire student views on the activities used in lessons, as well as an end of experience survey in the final teaching episode, in line with recommendations by Danley et al. (2016) and Marzano (2012). Exit ticket questions targeted how different activities enabled self-assessment, motivated students or helped them learn, yielding data for all three research questions. Questions were brief and clear, whilst avoiding leading responses (Munn & Drever, 1993). Open and closed questions, some with

scaled responses, were used to enable straightforward analysis in certain areas, whilst allowing students the freedom to explain their viewpoints.

Lesson reflections

Reflective journals can be an effective means of incorporating one's own opinions into data generation and analysis, as well as adapting the research process (Ortlipp, 2008). During and after each lesson I recorded my own reflections on how self-assessment impacted student learning and motivation, as well as what promoted or inhibited students' engagement in self-assessment activities. My own bias as an observer may influence my findings from this method but I have mitigated this by triangulating with other data sources (Evans, 2013).

Teacher observations

Teacher observations can address a variety of research questions, give insight into complex social interactions that are context specific and supplement data collected by other means (Moyles, 2002). Whilst observer bias remains an issue, I have triangulated with other methods to add reliability to findings (Evans, 2013).

In each lesson, at least one additional staff member was present (normally the class teacher and the teaching assistant for the ASD student). On each occasion, they noted their observations on an observation form I created targeted at identifying barriers and enablers to self-assessment in that lesson. Teacher observation provides an immediate account which can be discussed after the lesson, and the observers were familiar with the context of the school environment (Wilson & Fox, 2013). Inevitably, there are drawbacks: the observer must quickly decide what to record and thus the comments may be superficial or include observer bias. To mitigate this, I had regular discussions with the normal class teacher (the primary observer) which helped mould the observation form, lesson by lesson, into a format that was easier to complete. As such, the observation form was originally quite prescriptive, but evolved to a more open format, enabling more freedom for both specific and general comments.

Focus groups

Focus groups can offer an effective means of identifying shared attitudes and opinions of a group (ibid.). In this case, two focus groups were conducted in a semi-structured format after the 250-minute lesson sequence to glean the views of this year 12 physics class on what helped them self-assess and how self-assessment impacted their motivation and learning. Conducting the focus groups after having taught the class for a reasonable period of time allowed me to first establish trust with the participants, which aided discussion (ibid.). The first focus group included nine students, the second two. This allowed me to hear views across the spectrum of the class of fifteen, and probe individual views in more detail, particularly in the smaller group.

Ethics

I considered the ethical impact of this study in line with the framework outlined by Stuchbury (2013) and the Ethical Guidelines for Educational Research (BERA, 2018). I sought consent from students and the class teacher before commencing the study and informed students the purpose of the data I collected. For example, I explained that exit tickets would be used to assess students' learning, inform teaching and capture students' views on various lesson activities. Participation in focus groups was voluntary during normal school breaktime. I maintained an open dialogue with the normal class teacher, sharing emerging findings, and liaised with the teaching assistant of the ASD student regarding how lessons might impact him. Lindstrøm and Sharma's (2010, 2011) questionnaires on student motivation, which I used in the study, received approval from the Sydney University Human Research Ethics Committee, and I followed the administration guidelines. For instance, I informed students that resulting data would be used to evaluate my teaching (not them) to alleviate student anxiety. All data presented in this report has been anonymised to protect individual students.

Findings and discussion

Quantitative data

Energy concept test

Figure 2 illustrates the pre- and post-test results (marks out of 30). Each X denotes the mean score: 24.8 in the pre-test; 26.3 in the post test. The single data point in each test shows an outlier – this student's score was significantly below the rest of the class in both tests.

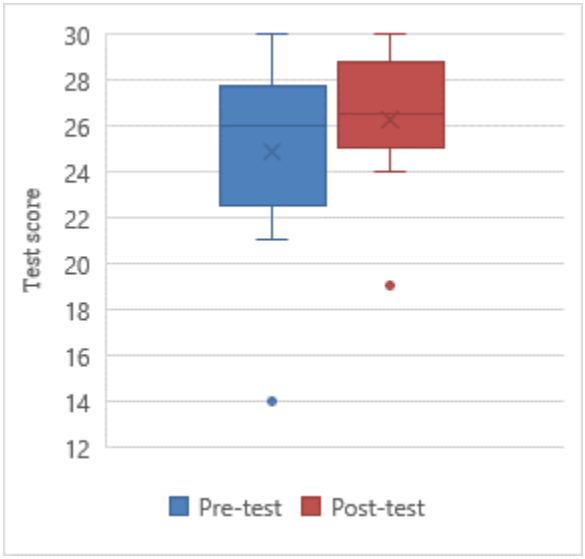

Figure 2: Box and whisker plot of the pre- and post- concept test scores out of 30

Students scored highly on the pre-test, limiting room for improvement. Nonetheless, Figure 2 shows a general increase in score, particularly at the lower end, which somewhat alleviates concerns that weaker students may benefit less from self-assessment (Black & Harrison, 2001). Although these results cannot confirm that self-assessment helped the students learn, they do indicate that the students *did* learn.

The pre-test also provided valuable data on the cohort's strengths and weaknesses, which informed teaching. For example, the pre-test revealed that students held the misconception that for a given mass, factors other than height (e.g. steepness of a slope) affected the transfer from gravitational potential energy to kinetic energy. Hence, in lesson 2 and 4 students completed and self-evaluated mathematical and conceptual questions involving such energy transfers in roller-coasters and rolling

balls. In addition, the pre-test aided student self-reflection by giving students an idea of what they would need to know by the end of the topic (ibid.).

Motivation questionnaire

Twelve students completed the motivation questionnaire. Table 4 summarises means scores of the class across the five motivation types (5 = strong agreement, 1 = strong disagreement).

Motivation type	**Mean score**		
	Pre-	**Post-**	**Change**
Mastery-orientation	4.3	4.4	+0.1
Performance-orientation	3.5	3.7	+0.2
Work-avoidance	1.9	1.7	-0.2
Cooperation-orientation	3.4	3.5	+0.1
Self-efficacy	4.0	4.2	+0.2

Table 4: Mean scores of the class in the pre- and post- motivation questionnaires

In general, the results in Table 4 show students have high mastery-orientation and self-efficacy but low work-avoidance, so may be well-suited to self-assessment (Seifert, 2004). Students also scored reasonably highly on performance-orientation – suggesting extrinsic motivators remain important to them – and cooperation-orientation – meaning that they are motivated in part by social goals. While the sample is too small for a rigorous statistical analysis, the results point towards a small increase in mastery-orientation and self-efficacy and a reduction in work-avoidance. This is supported by the data in Table 5, which shows that half of students increased their mastery-orientation and just over half increased their self-efficacy, while relatively few decreased in these areas, and students' work avoidance either decreased or remained unchanged. The data for performance-orientation and cooperation-orientation showed mixed responses.

Motivation type	**Number of students**		
	Increase	**No change**	**Decrease**
Mastery-orientation	6	3	3
Performance-orientation	6	0	6
Work-avoidance	0	7	5
Cooperation-orientation	4	4	4
Self-efficacy	7	3	2

Table 5: Changes in student motivation

It is worth noting, too, that students with lower mastery-orientation and self-efficacy in the pre-questionnaire generally increased in these areas, which suggests (albeit not conclusively) that self-assessment can positively impact such students, despite concerns that it is not well-suited to their existing motivations (ibid.).

Qualitative data

Both pupil and teacher voice data were collected, the former through exit tickets (ET) and focus groups (FG), the latter through comments from an observing teacher and teaching assistant and personal reflections. Below, I outline the coding process used to identify trends across the qualitative data, before analysing the findings in relation to each research question.

Coding

A mixture of deductive and inductive coding was applied to written and verbal comments to identify trends in the data (Evans, 2013). Responses were first coded by research question before a second level of predominantly deductive codes was applied from the literature. For RQ1 and RQ2 the impact of self-assessment was also categorised as either positive or negative. For RQ1, self-assessment appeared to positively impact learning through self-evaluation, self-reflection or self-regulation (Pintrich, 2000; Andrade & Du, 2007), while overlooking key concepts emerged as a potential negative impact on learning. For RQ2, positive impact on motivation generally related to supporting students' mastery-orientation or self-efficacy, while student engagement emerged as another key theme; negative impact generally related to self-assessment not supporting students' performance goals or enabling work-avoidance (Lindstrøm & Sharma, 2010, 2011). For RQ3, the barriers and enablers to self-assessment broadly related to: the resources or activities used to carry out self-assessment (see Table 1); the role of the teacher (Wanner & Palmer, 2018); and the capabilities and perceptions of the student (Bourke, 2016). Table 6 provides examples of how each type of qualitative data was coded, in line with Strauss and Corbin (1998), and Table 7 details the frequency of each code within the data.

Exit tickets provided a large volume of data, as shown in Table 7, given that they were completed by each student in each of the five lessons, while focus groups enabled richer discussion of emerging themes. Teacher observations and reflections, likewise, although smaller in volume, offered valuable insight into themes in learning, motivation and implementation. Further emerging

themes were identified within these second level codes which I explore in more detail in relation to each research question below.

Data type	Quote	Codes

Exit ticket, lesson 5	"Naming our strengths & weaknesses was really helpful as I now know what to revise"	• Impact on learning
		  o Self-reflection
		  o Self-regulation
		• Barriers/enablers
		  o Resources/activities

Lesson Reflection, lesson 1	"When reviewing mathematical questions, some students' interpretation of 'correcting' is just writing the correct answer not writing out a fully worked solution so that they understand"	• Barriers/enablers
		  o Resources/activities
		  o Student

Teacher observation, lesson 4	"[Students creating their own questions] fosters much deeper thinking. They seem to enjoy it! Might need more guidance."	• Barriers/enablers
		  o Resources/activities
		  o Teacher
		• Impact on motivation
		  o Engagement

Focus group 2	Q: "Did you find using the confidence grids [see Table 1] useful?"
	R: "Yes, usually I wouldn't think about the topic in that way, but this helps break it down into the different bits you're doing and I quite like that."
		• Barriers/enablers
		  o Resources/activities
		• Impact on motivation
		  o Self-efficacy
		• Impact on learning
		  o Self-reflection

Table 6: Examples of coding of qualitative data

Level 1	Level 2		Pupil voice		Teacher voice	
			Focus groups	Exit tickets	Personal reflections	Teacher observations
1. Impact on learning	Positive	Self-evaluation (Andrade & Du, 2007)	2	28	3	1
		Self-reflection (Andrade & Du, 2007)	3	3	-	2
		Self-regulation (Pintrich, 2000)	3	3	4	3
	Negative	Overlooking concepts*	-	-	4	2
2. Impact on motivation	Positive	Mastery-orientation (Lindstrøm & Sharma, 2010)	3	5	-	-
		Self-efficacy (Lindstrøm & Sharma, 2011)	-	2	-	-
		Engagement*	-	-	3	3
	Negative	Performance-orientation (Lindstrøm & Sharma, 2010)	2	12	-	-
		Work-avoidance (Lindstrøm & Sharma, 2010)	2	4	-	3
3. Barriers / enablers	Resources/activities*		7	71	12	15
	Teacher (Wanner & Palmer, 2018)		4	18	4	6
	Student (Bourke, 2016)		1	13	7	3

*Inductive codes are denoted by **

Table 7: Overview of second level code frequencies across qualitative data sources

RQ1: How does self-assessment impact learning?

Pupil voice data suggested that self-evaluation enhances learning through providing timely and insightful formative feedback, supporting self-reflection and self-regulation. For example:

> *"[It's] easy to find the source of mistakes when working the question out is fresh [in one's mind]."* (Student A, ET 4)

> *"I can easily and clearly see mistakes in my working so I can avoid similar errors in the future."* (Student B, ET 4)

Student A highlights that self-evaluation enables immediate feedback, while teacher-evaluation, for example, takes time (Dihoff et al., 2004). Student B alludes to the personalised insight that self-evaluation enables, which can benefit future learning. Another student noted it is "easier to notice mistakes" through self-evaluation than other means of assessment. Teacher observations and reflections, however, warned that self-evaluation can overlook a conceptual understanding, warranting appropriate teacher guidance (Wanner & Palmer, 2018).

Pupil and teacher voice data revealed that self-reflection helps guide future learning through enabling self-regulation, which in turn aids differentiation. For example:

> *"Naming our strengths & weaknesses was really helpful as I now know what to revise."* (Student C, ET 5)

Self-reflection has enabled this student to identify what to do to improve his future performance, promoting self-regulation (McMillan & Hearn, 2008). Indeed, the observing teaching assistant commented that self-reflection "allows [students] to apportion their time better", which McMillan highlights as a key metacognitive skill. Teacher observations and reflections revealed that encouraging students to self-regulate also supported differentiation, allowing students to work at their own pace. Furthermore, when students could choose and self-evaluate their own questions, they could complete a large amount of practice, which they cited as a key learning activity.

RQ2: How does self-assessment impact motivation?

According to students, self-assessment appeared to promote self-efficacy and mastery. Teacher-evaluation, however, seemed more motivating for students than self-evaluation. It proved difficult

to analyse student motivation in teacher observations and personal reflections, but what was often apparent was that students were engaged during self-assessed tasks.

Students regularly reported that self-reflection and self-regulation helped them understand what to do to improve. This could also enhance their belief that they can complete various tasks: self-efficacy (Bandura, 1994). When students were able to self-evaluate while completing a task (rather than waiting until after they had finished), the provision of detailed success criteria, enabling accurate and fast feedback, also promoted self-efficacy:

> *"If I have fully worked solutions, then I can know if I'm going in the right direction."*
> (Student D, ET 4)
>
> *"I like to know after the first question that I definitely get it before attempting the later, harder questions."* (Student E, ET 4)

However, an observing teacher raised concerns that some students, if allowed access to fully worked solutions while completing homework, would be tempted to copy the answers. Similar concerns over work avoidance (Lindstrøm & Sharma, 2010) were raised by students in focus groups and exit tickets. Nonetheless, activities involving self-evaluation appeared to promote mastery (ibid.). In the first focus group, six out of the nine students agreed that:

> *"Marking your own work is better at encouraging you to understand ideas for their own sake, rather than trying to impress the teacher."* (My wording, FG 1)

This stance was echoed in the second focus group, regarding teacher-assessed homework:

> *"I just have the feeling that when I'm doing homework I'm just doing it because the teacher told me to rather than just trying to understand it."* (Student F, FG 2)

Generally, then, it seems the students believed that self-evaluation supported mastery. However, they found teacher-evaluation most motivating, despite acknowledging that self-evaluation was best-placed to advance learning. This points to a conflict between motivation and learning, which presents a barrier to successfully implementing self-assessment. I discuss this in more detail below.

RQ3: What are the barriers and enablers to implementing self-assessment?

Key factors in implementing self-assessment were linked to: resources and activities, including task and assessment criteria (Torrance & Pryor, 2001); the role of the teacher (Wanner & Palmer, 2018); and the student (Black & Harrison, 2001; Bourke, 2016).

Questions on exit ticket 4 concerning students' views on assessing homework provided particularly rich data under each of these categories, revealing an underlying conflict between motivation and learning. For homework, students were generally required to complete and self-evaluate mathematical worksheets. Students were asked their opinion on how homework should be assessed to maximise learning (question 3) and motivation (question 4). The questions and frequency of responses are shown in Table 8.

3. When completing questions for homework, which of the following do you find most helpful to improve your understanding of the key physics ideas?	
Response	**Frequency**
a) Having the numerical answers to check my work as I go along	2
b) Having fully worked solutions to check my work as I go along	8
c) We self-mark answers during the following lesson	3
d) We peer-mark answers during the following lesson	1
e) My teacher collects in work to mark, and provides feedback in a subsequent lesson	0
4. When completing questions for homework, I am motivated to complete the work to the best of my ability if:	
Response	**Frequency**
a) I have the numerical answers to check my work as I go along	2
b) I have fully worked solutions to check my work as I go along	3
c) We self-mark answers during the following lesson	1
d) We peer-mark answers during the following lesson	1
e) My teacher collects in work to mark, and provides feedback in a subsequent lesson	9

Table 8: Student responses to exit ticket 4 questions on assessing homework

Thirteen students took part. One student circled both b and c for question 3 and one student circled c, d and e for question 4. Though this may skew the data slightly, these results have been included to ensure these students' views are captured. The following insights can be inferred from the data:

- the students believed that self-evaluation was better for learning than teacher- or peer-evaluation;
- the students found immediate and detailed feedback (i.e. provision of fully worked solutions) best for learning (in line with Dihoff et al. (2004) and Kearney (2013));
- the students found teacher-evaluation more motivating than self- or peer-evaluation.

Although most students preferred access to full solutions, both teachers and students voiced concerns over the temptation to use them to cheat: work avoidance (Lindstrøm & Sharma, 2010). Providing students with just numerical answers while they complete the work offers a solution to this problem. This approach enables timely self-evaluation, whilst mitigating against work-avoidance, and can encourage mastery (ibid.), as noted by one student:

> *"I keep working at a problem until I figure out how to do it myself rather than being tempted to just look at the mark scheme or not knowing I did it wrong until the lesson."*
>
> (Student G, ET 4)

Such mastery practice can also contribute to students' self-efficacy (Bandura, 1997) and help students internalise the monitoring and evaluation of learning (McMillan & Hearn, 2008). Full solutions could be provided in the following lesson to reveal key ideas which could otherwise be overlooked. The students' desire for teacher-evaluation could reflect a performance-orientation, where students are motivated by extrinsic factors such as the outcome of a task relative to their peers (Lindstrøm & Sharma, 2010). A subsequent teacher-assessment of students' workings and self-evaluation could make the students value the process more and enhance their motivation (Wanner & Palmer, 2018).

The teacher's role is not limited to assessment, however. The data showed that the teacher can support self-assessment through guidance, expectations and relationships with students. Observing teachers noted that self-evaluation can overlook an understanding of more challenging concepts, particularly amongst weaker students who are less skilled self-assessors (Black & Harrison, 2001). Teachers can offer an alternative and in-depth explanation of these questions, as noted by one student:

> *"[Teachers] can explain things in a different way."* (Student H, ET 5)

However, the teacher must be mindful of their relationship with the class (Harris & Brown, 2013). When students need to seek guidance from the teacher to advance their learning, it is important that they feel comfortable doing so. In addition, both students in focus group 2 noted that, although it did encourage them to try harder, the prospect of teacher-evaluation made them feel under pressure. Nonetheless, the expectations of the teacher seemed influential in how well the students engaged with a resource or activity.

"Resources" were a key enabler of self-assessment, according to an observing teacher. Each of the resources and activities introduced in Table 1 shed light on different barriers and enablers to self-assessment. In general, teachers observed that supporting these activities with clear task and assessment criteria (Torrance & Pryor, 2001) and appropriate teacher guidance allowed students to work autonomously but remain on-task. Students cited tests as a good self-assessment opportunity, although they still required prompting to self-reflect and identify the next steps to improve when they received their marked papers back. As such, tasks which explicitly address self-reflection and self-regulation (e.g. identifying strengths and weaknesses) seemed important enablers of self-assessment. Activities that incorporate the whole self-assessment spectrum (e.g. Isaac Physics questions, choosing and self-evaluating questions) can be particularly powerful as they help students internalise self-assessment as more than just self-evaluation (Bourke, 2016) and take ownership of their learning (Wiliam, 2011). Such activities also enable differentiation, as students can work at their own pace. Table 9 (next page) details the findings for each activity.

In addition to the activities in Table 9, I observed that class discussions and higher order questions appeared to offer valuable self-assessment opportunities. Class discussions helped explore concepts, whilst giving students responsibility for using their scientific views (Scott, Mortimer, & Aguiar, 2006). This enabled self-evaluation and self-reflection, as students were able to compare their ideas to those of their peers (and the teacher), connecting new knowledge, understanding and skills to those they already possessed (McMillan & Hearn, 2008). In focus group 2, the students noted that difficult questions and definitions aid self-reflection. For example:

> *"Definitions help you appreciate your level of understanding rather than if I can just put the numbers into formulae."* (Student E, FG 2)

Students also advocated regular low stakes tests to aid self-reflection and self-regulation, including "throwback tests" on topics covered earlier in the year.

Resource/ Activity	Findings
Confidence grid	This helped students self-reflect and self-regulate (Pintrich, 2000; Andrade & Du, 2007): "It helps let me know which topics I need to focus my revision on more" (Student G, ET 4); "I can track my progress easily" (Student A, ET 4). However, few students used it regularly – I noted that greater teacher expectations could support greater engagement with this resource.
Self-evaluating questions using mark scheme	Both students and observing teachers commented that self-evaluation is best suited to tasks where the success criteria are well-defined, for example, mathematical problems. More complex explanatory tasks are difficult to self-assess and require teacher guidance, especially due to students' concern over their self-evaluating skill (Harris & Brown, 2013).
Exit tickets	Most students agreed that answering the exit ticket problems followed by stating their confidence in a quick and easy format encouraged them to check their work and appreciate their own level of understanding, supporting self-reflection (Danley et al., 2016): "I thought about why I was confident which I found helpful" (Student E, FG 2).
Creating own examples/ questions	Teacher observations suggested this activity "fosters much deeper thinking" than other tasks but "might need more guidance". Students noted it provided a memorable way to link ideas: "It is more memorable than just answering questions as it is not something we usually do" (Student I, ET 4); "It got me to think about everything we have covered in order to create a good question" (Student E, ET 4). The teaching assistant noted, however: "Most ASD students find this sort of task far too difficult and stressful" as it is "too nebulous and ill defined". This activity also aided differentiation by allowing students to work at their own pace and create questions of appropriate difficulty for them, but students required practice and guidance to make incisive questions (Black & Harrison, 2001).
Derivations with hints	Allowing students to work independently on derivations appeared to encourage them to take ownership of their learning (Black & Harrison, 2004; Wiliam, 2011) but students required encouragement to use the available hints. An observing teacher noted these hints helped students process the mathematics but not necessarily the underlying concepts.
Isaac Physics questions	This platform provided an opportunity to: promote mastery (Lindstrøm & Sharma, 2010) by providing timely but limited feedback encouraging students to answer until correct (Dihoff et al., 2004); and self-regulation (Pintrich, 2000) by enabling students to choose the topic and difficulty of questions. Students commented on the "variety of interesting questions" and that it "helped improve understanding" but suggested the platform is best for consolidating existing knowledge: "It doesn't tell you exactly how you went wrong, if you know the topic well then it's good for practice" (Student I, ET 4).
Choosing questions	Students engaged with this activity, taking ownership of their learning (Wiliam, 2011), but observing teachers noted that some students may be tempted to choose questions they know how to answer, indicating work- or failure-avoidance (Seifert, 2004; Lindstrøm & Sharma, 2010), thereby not challenging themselves.
Revision	This task was not explicitly reviewed in the data, but students noted that self-evaluating practice questions and using the confidence grid helped guide revision, perhaps by prompting self-reflection (Andrade & Du, 2007) and self-regulation (Pintrich, 2000).
Test self-reflection	Several students cited this as useful for guiding future revision and learning (McMillan & Hearn, 2008; Bourke, 2016), whilst also improving self-efficacy (Bandura, 1994): "naming our strengths and weaknesses was really helpful as I now know what to revise" (Student C, ET 5).
Pre-topic concept test	This appeared to give students a context for their learning (Black & Harrison, 2001) as well as prompting self-reflection (Andrade & Du, 2007) and self-regulation (Pintrich, 2000). "It got me thinking about the topic and remembering content from GCSE" (Student E, ET 4); "I could get a feel for which parts I found hard and which bits I found easier" (Student F, ET 4); "[It] helps me identify what I need to work on - strengths & weaknesses" (Student J, ET 4).

Table 9: Impact of different self-assessment resources/activities

Other key factors influencing the impact of self-assessment included students' learning needs, ability, motivations and perception of self-assessment. For example, although creating their own questions proved a valuable self-assessment opportunity for some, the ASD student struggled with

the nebulous nature of the task. Such creative tasks can rely heavily upon the ability of the student, too – the more able tending to be better self-assessors (Black & Harrison, 2001). Students' goal-orientation can also impact how well they engage in self-assessment (Lindstrøm & Sharma, 2010). A key outcome of assessment for one performance-oriented student was to "see how you are getting on compared to others" (Student K, ET 4), so self-assessment may not have proved as motivating for him. Furthermore, students' perceptions of self-assessment may have limited its impact. In the first focus group students agreed that self-assessment comprises "marking your own work" and "correcting mistakes", neglecting self-reflection and self-regulation. Formally incorporating self-reflecting and self-regulating activities into lessons could thus encourage students to adopt a more sophisticated understanding of self-assessment, which could enhance their learning (Bourke, 2016).

Summary

Answering RQ1: How does self-assessment impact student learning?

Quantitative data indicates that students improved their conceptual understanding over the lesson sequence, and those with the weakest initial performance improved the most. Qualitative data suggests that self-assessment positively impacted learning through self-evaluation, self-reflection and self-regulation (Pintrich, 2000; Andrade & Du, 2007). Self-evaluation provides timely and insightful formative feedback (Dihoff et al., 2004; Wiliam, 2011), engages students with success criteria (Torrance, 2007) and prompts self-reflection. This in turn promotes self-regulation, which enables differentiation in the classroom and helps students identify and practice areas they need to improve, guiding revision. Self-evaluation can, however, overlook conceptual understanding.

Answering RQ2: How does self-assessment impact student motivation?

Quantitative data suggests that there was a small increase in students' mastery-orientation and self-efficacy and decrease in work avoidance over the lesson sequence (Lindstrøm & Sharma, 2010, 2011). Qualitative data indicates that self-evaluation promoted mastery goals amongst the students and supported their self-efficacy (Bandura, 1994). Encouraging students to self-reflect and self-regulate also promoted self-efficacy by helping students know what to do to succeed. Students were, however, motivated by performance goals, and teacher-evaluation proved more motivating than self-evaluation.

Answering RQ3: What are the barriers and enablers to implementing self-assessment?

Qualitative data indicates that resources and activities, the role of the teacher and the capabilities and beliefs of the student are important considerations in the implementation of self-assessment. The balance between learning and motivation prevents a key challenge: students believe that self-evaluation is best for learning, but teacher-evaluation is most motivating.

Activities with well-defined success criteria, for example mathematical problems, seem to be better suited to self-evaluation than explanatory tasks. Providing students with final answers to such tasks as they complete them enables immediate feedback, which can enhance learning and promote self-efficacy whilst mitigating against work-avoidance (Dihoff et al., 2004; Seifert, 2004). Online platforms (e.g. Isaac Physics) present an opportunity for students to practise questions and receive immediate feedback independently, promoting self-regulation and mastery (Pintrich, 2000; Lindstrøm & Sharma, 2010;). Other activities, however, such as higher order questioning, students creating their own questions and class discussions, still present opportunities for self-evaluation and self-reflection and help students critically engage with success criteria (Black & Harrison, 2001).

The teacher has an important role to play in self-assessment, through providing guidance, offering in-depth explanations of concepts and conveying appropriate expectations to motivate students (Wanner & Palmer, 2018). Students' abilities and learning needs also influence the implementation of self-assessment, with weaker students needing more guidance (Black & Harrison, 2001) and due consideration required for special educational needs and disabilities (SEND). In addition, students' perceptions of self-assessment are weighted towards self-evaluation (Bourke, 2016), therefore they should be exposed to activities explicitly encouraging self-reflection and self-regulation.

Implications

Implications for teaching practice

This study suggests that the regular use of self-assessment over a lesson sequence for a year 12 physics class studying energy offered benefits for students' learning and motivation. Self-assessment can enhance learning by providing timely and insightful feedback, promoting self-reflection and self-regulation (Pintrich, 2000; Dihoff et al., 2004; Andrade & Du, 2007). Encouraging students to self-assess can focus them on mastery goals and support their self-efficacy,

which is conducive to learning (Bandura, 1994, 1997; Lindstrøm & Sharma, 2010, 2011). Key considerations for implementing self-assessment include the resources and activities used by students, the guiding role of the teacher, and the capabilities and motivations of the student.

Based on the findings, I offer three more specific messages that practitioners using self-assessment in the classroom may wish to consider:

- Self-assessment is more than just students marking their own work (Andrade & Du, 2007). Higher order conceptual questioning, class discussions and creative tasks, for example, provide valuable self-assessment opportunities, despite students not formally self-evaluating. In addition, students' perceptions of self-assessment neglect self-reflection and self-regulation. By explicitly demanding students to reflect on their strengths and weaknesses and identify what they can do to improve, this can foster a culture of continuous self-assessment in the classroom, overcoming the emphasis on summative assessment prevalent in UK education, and enhancing students' self-efficacy and future learning, whilst also enabling differentiation (Harris & Brown, 2013; Bourke, 2016).

- Mathematical problems offer a valuable and convenient self-assessment opportunity for students, particularly for self-assessing homework. Providing students with answers – but not full solutions – to check their work as they complete it can foster mastery and self-efficacy (Bandura, 1994, 1997; Lindstrøm & Sharma, 2010, 2011). A subsequent teacher-assessment provides an extrinsic motivator and can help explore key concepts. Online resources, such as Isaac Physics, offer a platform for students to work autonomously in this fashion, receiving immediate right-or-wrong feedback, with unlimited opportunity to re-attempt questions.

- The teacher has an important role to play in self-assessment (Wanner & Palmer, 2018). Teacher input is vital to highlight and explore key concepts which can be overlooked during self-evaluation; teacher guidance can facilitate discussions and help students self-regulate; and the teacher's expectations are important for motivating students.

Strengths and limitations

Many of the findings put forward in this study are supported in the literature. Whist some papers cited focus on higher education (Lindstrøm & Sharma, 2010, 2011; Wanner & Palmer, 2018) or on

schools outside the UK (Harris & Brown, 2013; Bourke, 2016), Black and Harrison (2001) explore self- and peer-assessment in science within UK secondary schools, making their insights particularly relevant. Their report is grounded in the formative assessment literature (Black & Wiliam, 1998) and advocates the benefits of self-assessment in terms of immediate formative feedback and the ongoing process of students guiding their own learning, in line with those I have found. Black and Harrison (2001) also advocate many of the self-assessed tasks and activities which I have used (e.g. marking homework, creating questions, the confidence grid based on Black and Harrison's "traffic-lighting").

There are limitations my findings, however, given the small sample size and relatively short duration. Some findings may also be context-specific. The class under investigation was a relatively high-attaining group of 15 male year 12 physics students, all of whom were predicted a grade C or above. Stronger (and older) students are better self-assessors (Black & Harrison, 2001) and have more sophisticated perceptions of self-assessment (Bourke, 2016). Mathematical tasks with clear success criteria, which are frequently used in physics, seem better suited to self-evaluation. Thus, self-assessment may be particularly beneficial to a strong cohort studying A-level physics, but less well-suited to a mixed ability year 7 class studying English, for example. Given the class was all male, there may also be gender-specific considerations not revealed by this study (indeed Lindstrøm and Sharma (2011) found significant differences in self-efficacy between male and female physics students). In addition, successfully implementing and honing self-assessment strategies in the classroom takes time (Black & Harrison, 2001), and the students in this case study had previous experience in self-assessing their work. Thus, for students less well-versed in self-assessment, benefits may only reveal themselves in the longer term.

Future research

Although there is substantial evidence in the existing literature that self-assessment yields benefits for student learning and motivation, relatively little research has been conducted into how self-assessment should be designed and implemented (Harris & Brown, 2013; Wanner & Palmer, 2018). This study suggests that the resources and activities used to carry out self-assessment play a key role in its impact. Whilst Black and Harrison (2001) offer a commentary on the impact of several such activities, the design and implementation of self-assessed resources and activities in a secondary school context presents a possible avenue for future research.

Homework is an area where self-assessment can prove particularly valuable – students must work autonomously, so assessing their work as they do it can add value. Moreover, if students can self-regulate, they can tailor their homework to suit their learning needs, provided the task allows this. Online resources present a platform for immediate feedback and self-regulated learning, but students must still evaluate and reflect on their work to improve. Some pertinent research has been conducted into how self-assessment can be used alongside science and maths homework in schools (Newby & Winterbottom, 2011; Dubland, 2015), which supports themes evident in this study, such as the importance of clear assessment criteria (Torrance & Pryor, 2001), students' perception of self-assessment (Bourke, 2016) and what motivates them (Lindstrøm & Sharma, 2010, 2011). The use of online homework has also been shown to enhance learning of physics (Cheng, Thacker, Cardenas, & Crouch, 2004), engineering (Balta, Perera-Rodríguez, & Hervás-Gómez, 2018), mathematics (Butler & Zerr, 2005) and foreign languages (Sagarra & Zapata, 2008) in higher education, with students citing the benefits of immediate feedback and the opportunity to re-attempt questions. However, further research into synergies between self-assessment and different types of homework in secondary education, with a focus on exploiting students' access to online resources – which are more available to students than ever before – could add valuable insight to the formative assessment literature.

Conclusion

Self-assessment is a complex metacognitive process which is uniquely placed to advance student learning (Bourke, 2016). Not only can it offer timely and insightful formative feedback, it can empower students to recognise their strengths and weaknesses and take an active role in monitoring and guiding their own learning (Wiliam, 2011). The teacher, nonetheless, should remain a prominent figure, offering guidance and conceptual insight (Wanner & Palmer, 2018), and tailoring the process to suit individual students.

Through a combination of quantitative and qualitative data, this study indicates that a sequence of lessons on energy employing a variety of self-assessment methods offered benefits for the learning and motivation of students in a year 12 physics class. Timely self-evaluation of mathematical questions can enhance learning and foster students' mastery and self-efficacy (Lindstrøm & Sharma, 2010, 2011). When given as homework, such tasks can be supported by giving students access to numerical answers to check their work as they complete it, before a subsequent teacher-

evaluation. Tasks explicitly demanding self-reflection and self-regulation also appeared to promote students' metacognition and enhance their perception of self-assessment, offering benefits for learning and motivation in the longer term (McMillan & Hearn, 2008; Bourke, 2016).

Homework, particularly, appeared to offer an important self-assessment opportunity. This presents an avenue worthy of further research, with an emphasis on the use of online resources, which offer students a perhaps unparalleled opportunity to take ownership of their learning in the digital age.

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