LEARNING, TEACHING, AND ASSESSING CHALLENGING BIOLOGY CONCEPTS AND PROCESSES USING TEACHER CONSTRUCTED POWERPOINT ANIMATIONS

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Abstract

The role of practical work in secondary school science in schools in England has changed since the government White Paper of 2010 [1] initiated major reforms to school curricula and assessment in England. These reforms removed assessed practical coursework from school leavers' external qualifications in Science, Technology, Engineering and Mathematics (STEM) subjects and has increased the use of other subject specific pedagogies. The Assessment and Qualifications Alliance (AQA) is typical of the examination boards that produced compliant Certificate of Secondary Education (GCSE) and General Certificate of Education Advanced Special/Advanced Level (GCE AS/A-level) biology specifications ready for examinations from 2018 and 2016 respectively [2][3]. This paper refers to the subject knowledge content required for AQA biology specifications [2][3].

Both the substantive subject knowledge (concepts and ideas) and disciplinary knowledge (investigational knowledge and skills) in the AQA specifications are assessed by written examination [2][3]. Osborne [4] summarised the arguments that probably influenced this assessment reform moving away from the direct assessment of practical work and noted that much practical work in secondary science lessons was not effective in teaching scientific ideas. There is a case for using other pedagogies for teaching biological ideas [4] and a meta study by Cavagnetto [5] has suggested that activities immersing learners in scientific argumentation are most effective for improving scientific literacy including concept development. Animated representative models can be used in biology as a learning, teaching, and assessment (LTA) strategy to promote discussion and argumentation and there is some evidence for their effectiveness [6].

This paper reports the use of homemade PowerPoint animated models as an LTA strategy to represent complex concepts and processes found on biology examination specifications [2][3]. PowerPoint animated models were developed with pre-service teachers at a qualified teacher status (QTS) provider in the northwest of England and the construction, manner of use, advantages and disadvantages of two examples are discussed. The main advantage of using a homemade animation was identified as the opportunity to construct it to fit with the key points in the specification to be examined. The main disadvantage was the time taken to make the animation.

Keywords: Secondary school biology, Learning, Teaching, Assessment, PowerPoint, Animation, Representative models, Pedagogies, Public examinations, Pre-service teachers.

1 CONTEXT

Concerns about the purpose and efficiency of practical work in science lessons [4] and the challenges faced by teachers conducting coursework assessments towards external examinations in English schools contributed to the education reforms initiated by the Government White Paper of 2010, *The importance of teaching* [1]. In science subjects, teacher assessed investigations that contributed to final grades were replaced by a list of teacher accredited practicals, and only those investigation skills that could be assessed by written, end of course examinations were included in external examination grades [1] [2] [3].

Alongside other examination boards, The Assessment and Qualifications Alliance (AQA) produced compliant examination specifications for General Certificate of Secondary Education (GCSE) and General Certificate of Education Advanced Special/Advanced Level (GCE AS/A-level) biology specifications ready for examinations from 2018 and 2016 respectively [2][3]. These biology specifications [2] [3] are used in this paper as typical examples of substantive and disciplinary knowledge content currently examined in one Science, Technology, Mathematics, and Engineering (STEM) subject in England.

The education reforms [1] also removed modular routes from the assessment of national qualifications. The reduction in curriculum time required to develop biology practical skills combined with the necessary emphasis on efficient learning, retaining and retrieval of biological concepts for end-test only examinations has resulted in renewed teacher interest in learning, teaching and assessment (LTA) strategies based upon cognitive mind theory and constructivist learning encapsulated in approaches such as Rosenshine's Principles [7].

There are many pedagogies that can serve the same purposes that science teachers intend for practical work [4]. Some are more efficient than practical work in helping learners develop the type of experimental design and data handling skills assessed easily by written examinations. A meta-study by Cavagnetto [5] suggests that activities immersing learners in scientific argumentation are most effective for improving scientific literacy, which contributes to both substantive and disciplinary knowledge in a subject. This paper discusses the use of animated representative models in biology as an LTA strategy that can be used to promote discussion and argumentation. There is some evidence for their impact on learning [6]. It is proposed that the use of in-house constructed animations has multiple applications and are worth the time spent in their construction as the teacher can maintain control of the steps that learners see and restrict these to assessed key points in the examination specification.

2 GENERAL CONSIDERATIONS

The government education White Paper of 2010 [1] indicated a move away from skills-based curricula for schools in England, and placed subjects and knowledge at the forefront of curriculum design. Osborne [4] criticised the poor quality of much practical work in science lessons, perceiving it to be often without a clearly defined purpose and liable to contribute to the hidden curriculum in a negative way. Learners could struggle with equipment that did not work, wander off task, and often fail to understand the relevance of practical exercises to the theoretical content of lessons [4]. Further, Osborne would argue that it is usually better to replace practical work with an alternative pedagogy if the aim of the exercise is to learn science concepts, understand them, and retain them for recall [4]. There are many types of science practical work, which can be organised in a variety of ways with various benefits and challenges (Fig. 1). Resources, technical support, and risk assessment often dictate how practical work can be organised with a particular class, if it can be attempted at all. There is always an educational risk/benefit ratio balancing potential learning gains with challenges that the teacher needs to meet (Fig. 1). However, learning investigational and problem-solving skills through successfully managed practical work and the immersive argumentation it can generate is unique to science subjects and the reason for their inclusion in the school curriculum. Its continued inclusion in science lessons should be defended by STEM teachers.

However, Osborne [4] has some justification for proposing that practical work is not an efficient pedagogy when the aim of a lesson is to teach and learn science content. There are too many competing task related distractions for efficient concept learning, although other relevant skills and knowledge may be gained in the process. Modelling is one versatile alternative strategy. Although there are many types of models, the in-house PowerPoint animations discussed here are examples of two-dimensional representative models. O'Day [6] reported positively on the impact of biology animations on long term memory, but there is little other research into the use of animations in school biology LTA. Nevertheless, anecdotal evidence and personal experience suggests that animations can be used effectively in a variety of ways during unsupported, paired, group, and class activities.

PowerPoint presentations and the use of interactive wipe boards linked to laptops are becoming widespread in schools in England at all phases of education. PowerPoint is part of the Microsoft Office suite of applications and has simple to use drawing and shape insertion facilities, with slide transition effects and text and object animation effects. Combined with simple 'flick-book' motion techniques, most processes and structural movements illustrated in biology textbook diagrams can be simplified and animated to emphasise teaching points required by examination specifications [2] [3]. The animations can be set to play on a continuous loop or can be shown in 'stop frame' mode by interrupting the continuous play and manual clicking to move the animation on.

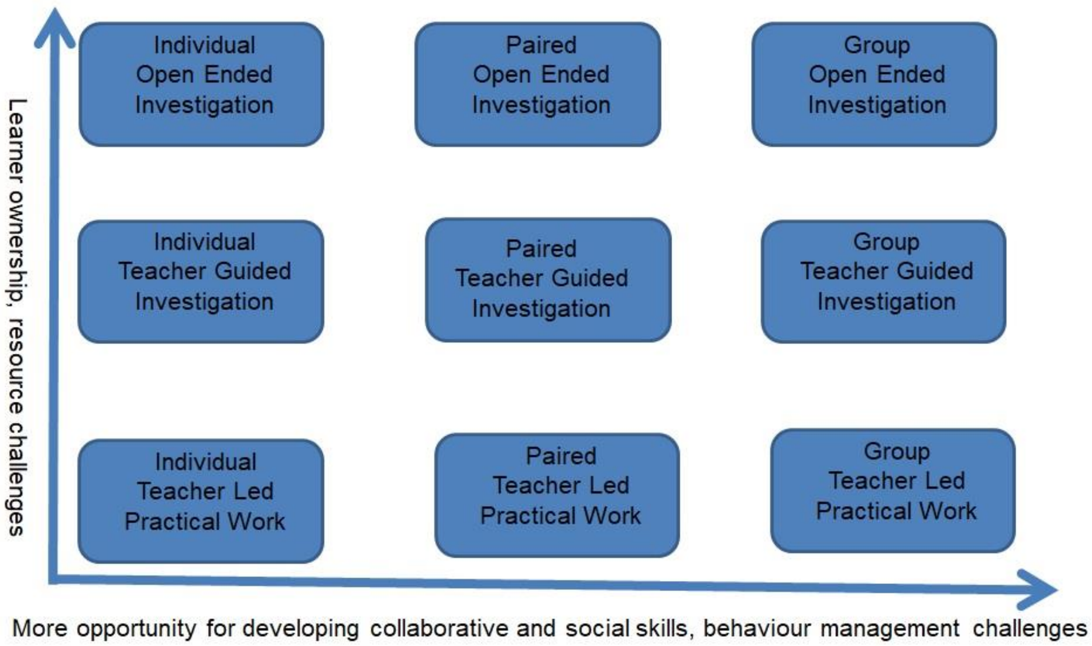

Figure 1 Ways of organising science practical work

3 METHODOLOGY

Over several years self-constructed biology PowerPoint animations were shared with pre-service teachers attending initial teacher education (ITE) programmes at a higher education (HE), qualified teacher status (QTS) provider in the northwest of England. Their origins were the tutor's own animations constructed during their teaching career with others added by pre-service teachers over the tutor's years as a teacher educator. The pre-service teachers were free to use the resources with or without amending them. The way in which they had been used in class and their impact on learners were discussed in subject pedagogy sessions on non-school training days. This article is written from participant observations of sessions and pre-service teachers' written references to the animations from ITE programme activities involving subject specific pedagogies. Two examples were selected to illustrate the use of self-constructed PowerPoint animations, and their advantages and disadvantages. This constitutes a pedagogical study with no ethical implications.

4 FINDINGS AND DISCUSION

4.1 Strategies for using the animations

Most of the pre-service teachers were attached to the same school experience placement school for the majority of the time during their ITE programme. Many of the placement schools followed Rosenshine's Principles [7] to varying extents, or were advocates for this or similar guideline schemes for lesson planning and structure. The following approaches were cited in subject pedagogy sessions by the pre-service science teachers as most useful to them during biology lessons and consistent with their schools' approaches to planning and lesson structure:

- **Unsupported individual starter activities.** On arrival at the lesson, learners were given a prompt sheet directing them to record what the animation shapes represented and the changes occurring as the animation looped. Once the class were all engaged, the teacher circulated the room to keep learners on task and make interventions. After five to ten minutes the animation was stopped, and the teacher went through each slide to correct errors and reinforce appropriate answers. This could be used as an introduction to new work, establishing prior knowledge, a retrieval practice [8] or as a recap of previous lessons. The underlying learning theories for this approach were cognitive [9], constructivist [10] and behaviourist [9].

- **Individual formative assessments:** At a review point or at the end of the lesson the animation was used in a similar way to the individual starter activity above. However, the animation time was usually reduced and the class discussion and feedback time increased. The purpose was assessment for learning following the principle that it included all the learners in the class in formative assessments and aimed to develop independent and self-evaluative learners who understood the criteria for assessment.
- **Think, pair, share activities:** As a part of the main lesson the teacher grouped learners on tables for the activity, mixing learners with different level of expertise in the topic. The animation was played for a minute or two whilst learners were asked to label parts and describe events individually. They were then asked to discuss their individual responses with their nearest partner for a few minutes and agree or amend their responses as appropriate, followed by a slightly longer table discussion to arrive at a group explanation or description. The teacher then debriefed the activity by explaining each slide. This was a cognitive constructivist [9] and social constructivist [11] approach recognising the importance of peer conversation in concept development and the influence of more expert peers on less expert peers' zones of proximal learning [11].
- **Argumentation and cognitive conflict:** Teachers wanting to promote argumentation and cognitive conflict adopted the strategy of asking the learners to complete a think, pair, share activity, but when debriefing the activity would ask two groups to report their explanation of the animation. However, a third group expecting to do the same was then asked to compare the first two explanations and tell the class the similarities and differences between the first two groups' accounts [5].
- **Teacher exposition and explanation:** Teachers simply played the animation then explained what each slide represented. This preceded practical work or a practical demonstration on the topic in order to locate it in the topic.
- **Learner constructed PowerPoint animations:** Learners already familiar with such animations were asked to amend existing PowerPoint animations or construct them from first principles to illustrate a concept or process. This was a creative process starting with the information from the examination specification and allowing learners to apply this to the production of a personal revision aid.

4.2 Osmosis: A GCSE example

Several statements describe the concept of osmosis in the AQA GCSE biology specification [2]. To qualify as osmosis there must be movement of water across cell membranes [2]. Cell membranes are described as partially or semi permeable, allowing small water molecules to pass through whilst preventing or slowing the passage of larger molecules such as glucose. Osmosis is defined as the diffusion of water from a dilute solution to a concentrated solution, implying that the water molecules are moving in random directions so that, overall, more are moving away from the dilute region than are replaced by molecules arriving from the concentrated region. Learners are expected to be able to recognise, draw and interpret diagrams of osmosis.

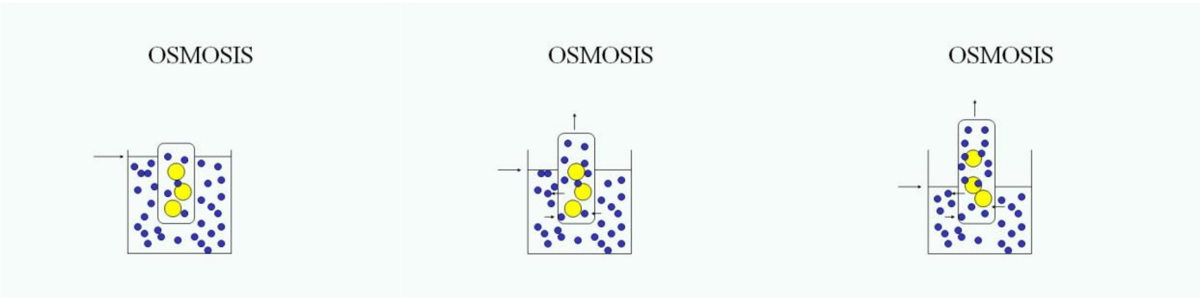

Figure 2 Three osmosis PowerPoint slides that cycle quickly on a continuous loop

Fig. 2 shows that the osmosis PowerPoint animation as a simple continuous loop of three slides with relatively few changes occurring in each cycle and no text or object animations. Learners can be asked to watch the animation and label the components on a static diagram. They can then observe and notice what is happening as osmosis occurs. In the osmosis animation shown in Fig. 2 arrows emphasise the net movement of water molecules into the membrane bound structure, the external level of the water dropping, and the membrane bound structure increasing in size. The number of water molecules inside the structure increases but the number of solute molecules (usually named as glucose by learners) remains constant, implying the membrane boundary is semi-permeable. The increase in size of the membrane bound structure can be linked to the required practical skill associated with this section of the specification: calculating percentage changes in mass of plant tissues in solutions of different concentrations [2]. The sequence can be stopped on each slide for learners to discuss and confirm their observations. This can be used as an unsupported activity at any stage in a lesson, a discussion piece, or as a plenary assessment of learners' understanding of the concept of osmosis.

4.3 The light-dependent reaction of photosynthesis: A GCE A-Level example

The AQA GCE A-Level biology specification [3] requires this complex process to be understood is terms of the following steps:

1. chlorophyll absorbs light, leading to photoionisation of chlorophyll
2. some of the energy from electrons released during photoionisation is conserved in the production of ATP and reduced NADP
3. the production of ATP involves electron transfer associated with the transfer of electrons down the electron transfer chain and passage of protons across chloroplast membranes and is catalysed by ATP synthase embedded in these membranes (chemiosomotic theory)
4. photolysis of water produces protons, electrons and oxygen
5. the light-independent reaction uses reduced NADP from the light dependent reaction to form a simple sugar
6. the hydrolysis of ATP, also from the light-dependent reaction, provides the additional energy for this reaction

The animation illustrated in Figure 3 demonstrates these points and indicates the involvement of the two types of chlorophyll molecule located in the thylakoid membranes of the chloroplasts. Normally, this animation would be preceded by a revision animation showing the physics of the interaction of light with transparent and opaque materials: reflection, refraction, and absorption with subsequent re-radiation of heat. This is to introduce the concept of energy levels, promotion of electrons, unstable and stable ledges, and molecules as energy transducers. The light-dependent reaction animation represented in Fig. 3 comprises of nine slides incorporating stop action animations and object animations within certain slides. It was quite complex even taking into consideration the simplification of the process described in the AQA specification [3].

The green boxes and purple cylinders represent chlorophyll a and chlorophyll b acting as two different photosystems linked by a purple wave representing the carrier chain. A short purple wave carrier chain requires the presence of hydrogen ions, electrons, and a carrier molecule to compete the reaction. White circles represent hydrogen atoms and red circles oxygen. Ions have their charge assigned. The animation shows the stages described in the specification [3] in sequence with no extra detail.

The first three slides shows a photon of light absorbed by chlorophyll, promoting a pair of electrons to an elevated energy level and the splitting a water molecule into hydrogen ions and oxygen, photoionisation and photolysis. The electrons from the water molecule replace those promoted.

The second set of three slides show the electrons descending the electron carrier chain supplying energy for the generation of adenosine triphosphate (ATP). A second chlorophyll molecule receives the electrons and uses the energy from the absorption of a second photon of light to re-promote them to higher energy state.

The last triplet of slides shows a hydrogen carrier, nicotinamide adenine dinucleotide phosphate (NADP), combining the electrons reaching the end of the second carrier chain with hydrogen ions from photolysis to form $NADPH_2$. The final slide shows $NADPH_2$ and ATP, the products of the light-dependent reaction of photosynthesis available to participate in the Calvin-Bensen Cycle or light-independent reaction of photosynthesis, providing hydrogen and energy to reduce carbon dioxide by converting it into simple carbohydrates [3]. The oxygen is shown in its true diatomic state.

Identifying the biological components represented by the simple shapes taken from the PowerPoint Insert Shapes menu was not too much of a problem for most A-Level learners. The animation was used in a variety of contexts, as a continuous loop or slide-by-slide, for individual learning, paired and group discussion, explanation exercises, and formative assessment of key concepts. Even with the animation focusing on the specification key points [3], only more able A-Level learners were able to utilise the animation un-supported as a loop. Once learners had been taken through the animation slide by slide, they were often able to use the loop animation effectively in revision sessions.

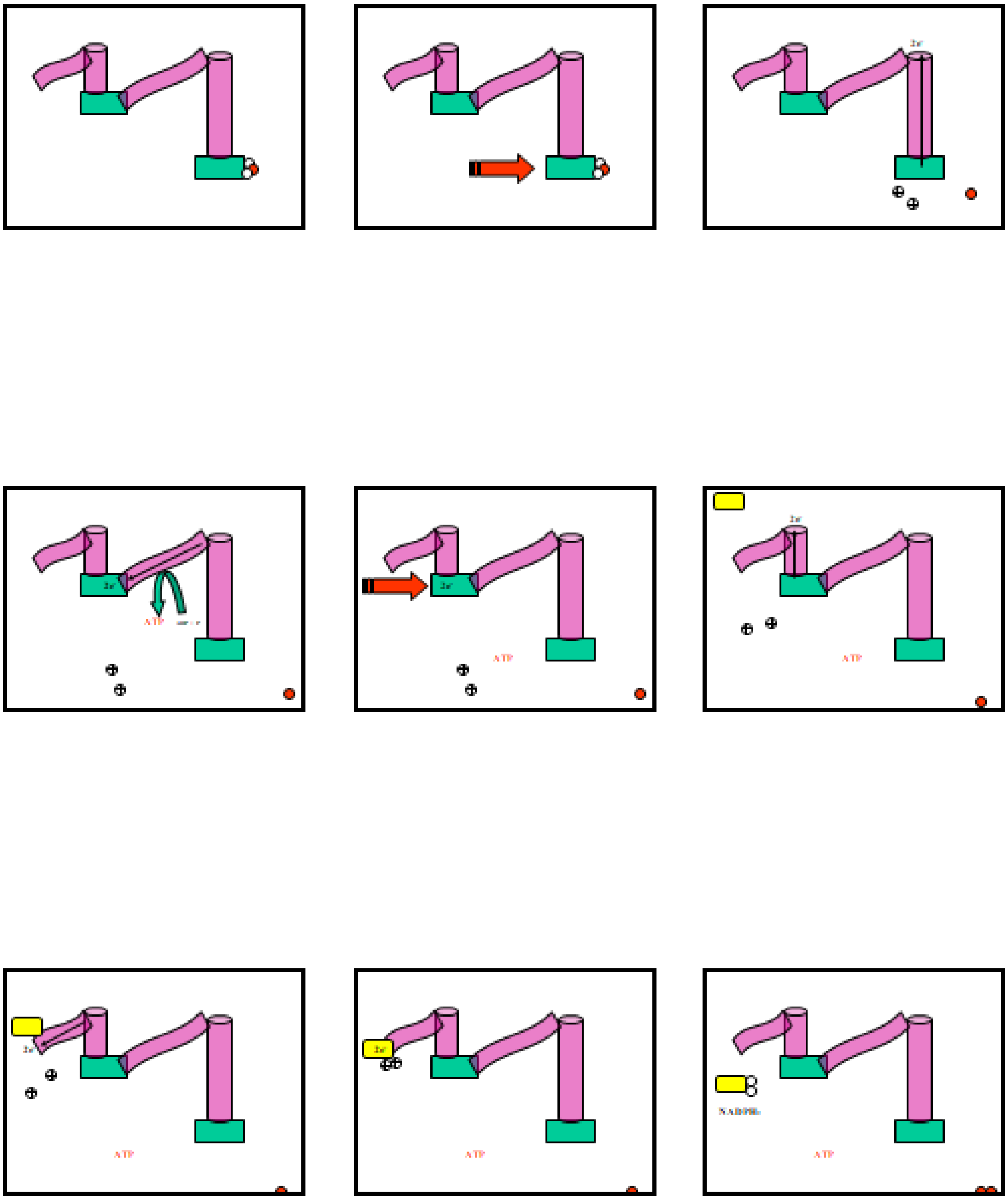

Figure 3 The light-dependent reaction animation slides

4.4 Advantages and disadvantages

The pre-service teachers welcomed the sharing of teacher constructed PowerPoint animations as an LTA resource and some added to the resource with their own animations. Those who were familiar with PowerPoint animation effects reported that the time needed to construct an animation decreased after their first attempts and that initially planning the sequence on paper was usually quicker than trying to plan in PowerPoint. However, they also reported that their first and quickest course of action was to search the internet for 'off the shelf' free resources and that they had found some very useful animations from reliable sources such as science subject associations, BBC BiteSize and those recommended by the Association for Science Education (ASE). However, if they could not find of-the-shelf resources that related directly to their examination specification or learners, these were often difficult to edit or amend and they then attempted their own animations from first principles.

Some internet animations were attractive and used professionally produced, and sometimes quite sophisticated artwork, graphic design and animation. However, the simplicity of the diagrammatic shapes and control over slide transitions and animation effects time length in the teacher produced PowerPoint animations could be more effective in directing the attention of learners to specific points of interest. On the other hand, if the animations were too crude and simplistic, this could have the opposite effect.

A major disadvantage of all representative models is their potential to cause misconceptions in the minds of learners. The GCSE example osmosis animation would be too confusing if the particles were also animated. The water and glucose molecules should move at different velocities in random directions, colliding with each other and the solid boundaries of the container and membrane structure. Some learners may erroneously think, based upon the osmosis model, that the particles are stationary. The light-dependent reaction animation explains the energy transducer role of chlorophyll well, but gives the impression that the process is linear and sequential. It also fails to indicate the dynamic role of enzymes and mosaic arrays of enzymes, chlorophyll molecules, electron carriers, and proton pumps in the thylakoid membranes. However, the purpose was to emphasise the main conceptual points in the examination specifications [2] [3], and so both models were content valid.

5 CONCLUSIONS

Animations can be used in a variety of ways to aid learners in their development of complex biology concepts and understanding of processes. They can also be used to assess learners' ability to explain and apply both.

Well-designed teacher constructed PowerPoint animations can ensure that learners focus only on examination specification content points that will be assessed.

The teacher constructed PowerPoint animations were found to have many uses that were consistent with influential learning theories and guidelines for lesson structure and planning.

Representational models are efficient LTA tools when compared to learning concepts and processes by experiencing a wide range of concrete examples, non-examples and apparent exceptions. However, models can only emphasise some aspects of a concept or process and necessarily ignore and omit others. For this reason, the use of any representative model risks the introduction of misconceptions to minds of learners that will need to be challenged and amended at a later date. By focusing on examination specification content points the use of teacher constructed PowerPoint balances the risk of misconceptions against the assessment requirements of the specification and the learners' need to demonstrate attainment.

Teacher constructed PowerPoint animations are satisfying to produce but consume lesson preparation time. The teacher constructed PowerPoint animations resource was shared with pre-service teachers on an ITE programme to save them preparation time, The animations were varied in their aims and level of sophistication, and not always appropriate to the pre-service teachers' requirements. However, they were easy to edit and amend for different purposes with different learners. Pre-service science and biology teachers found them useful to save time in planning and preparing materials even when they required amendment. Experiencing the editing process made it more likely that they would re-purpose or construct animations from first principles.

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