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DALDIS: Pedagogical Guidelines

Authors:

Dr Marion McGinn – Learnovate (TCD)

Prof. Inmaculada Arnedillo-Sánchez SCSS (TCD)

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LIST OF ABBREVIATIONS

Abbreviation	**Explanation**
CBA	Classroom Based Assessment
EEI	Extended Experimental Investigation
ISCED	International Standard Classification of Education
JCPA	Junior Cycle Profile of Achievement
OECD	Organisation for Economic Co-Operation and Development
PISA	Programme for International Student Assessment
SCSS	School of Computer Science and Statistics
SEC	State Examination Commission
SLAR	Subject Learning and Assessment Review
STEM	Science Technology Engineering and Mathematics
TCD	Trinity College Dublin

INTRODUCTION

Formative assessment, providing feedback to students, and utilizing approaches that motivate and incentivise students create a strong learning experience. The assessment for learning methodology of the DALDIS (Digital Assessment for Learning Informed by data to motivate and incentivise Students) project is built on the principle that formative assessment is one of the best methods to encourage student achievement (Hattie, 2009). The benefits of formative assessment translate into positive effects for both teachers and students (Baleni, 2015). However, there is evidence to suggest that it can be challenging for teachers to adopt formative assessment in their classrooms. These barriers can include; time for teachers to develop the skills needed to provide detailed feedback and engage students in tasks to demonstrate learning, and understanding how to use students' feedback to adapt their own teaching and learning (Hopfenbeck et al., 2015). Our approach to assessment together with the use of technology, attempts minimise some of the barriers associated with the use of formative assessment in the classroom. Namely, teachers' need for time to develop formative strategies, their knowledge of formative approaches, and well-designed questioning and feedback content to support the methodology in the classroom.

Formative assessment has been defined as any interaction that generates data on student learning and is used by teachers and students to: inform teaching and learning; address specific student learning difficulties; and, support learning growth over time (Lane et al., 2019). The benefits of this approach are that teachers can assess learner's comprehension so that, teaching can be modified, and further learning informed through continuing and timely feedback until the anticipated level of understanding has been accomplished (Baleni, 2015). Currently teachers use a broad range of formative assessment methods from which information about students can be gleaned, such as observation, quizzes, tests, portfolios, class discussions, and homework. This is in contrast to *summative assessment* which measures learning following a period of instruction and is generally assigned a numeric grade or defined performance categories. For instance, "Yet to meet expectations", "In line with expectations", "Above expectations," and "Exceptional". While summative assessment provides a record of a student's learning on a prearranged day, under exam conditions, the purpose of formative assessment is to gain an understanding of what students know and don't know during the learning process and identify their strengths and weaknesses. According to Pellegrino (2013), assessments should be based on what teachers and educational policymakers expect students to know and understand about an aspect of a topic. For example, if assessment is not supported with the aims of the learning process, its validity is jeopardised and this can hinder students' learning (Baartman et al., 2006).

Technology assisted assessment is seen as a promising way to promote formative assessment practices in schools (Russell, 2010). It has the potential to reduce teachers' grading time and can provide a variety of item types which allow the incorporation of text, animation, video and audio-visual information**.** Technology assisted assessment offers advantages over traditional forms of assessment as it is electronically built and can generate user data on assessment activities (Nguyen et al., 2018). In addition, assessments embedded in technology can enable various types of assessments such as: Diagnostic, used to determine a students' knowledge level and administered prior to learning to identify information about a student's needs and strengths; Formative, conducted during the instructional process; and Summative, conducted at the end of the instructional process. Several researchers such as Elmahdi et al., (2018) and Charman (2000) identify the following advantages that technology can offer for formative assessment over pen and paper:

- Immediate data about students' understanding of a topic.
- Repeatability.
- Immediacy of response to the student.
- Supports individualized learning.
- Reliability and equitability.
- Markers are not influenced by the presentation.
- Timeliness – potential for assessments to be used at the most appropriate time.
- Flexibility of access.
- Encourage student interest and motivation.
- Transforms the classroom from teacher-centred to student-centred.

According to the report, *Transforming Education: Assessing and Teaching 21st Century Skills* (Kosma, 2008), other benefits of using technology for assessment include:

- Reduced costs of data entry, collection, aggregation, verification, and analysis.
- The ability to adapt tests to individual students, so that the level of difficulty can be adjusted as the student progresses through the assessment and a more-refined profile of skill can be obtained for each student.
- The ability to efficiently collect and score responses, including the collection and automated or semi-automated scoring of more-sophisticated responses, such as extended, open-ended text responses.
- The ability to collect data on students' intermediate products, strategies and indicators of thought processes during an assessment task, in addition to the student's final answer.
- The ability to take advantage of ICT tools that are now integral to the practice and understanding of subject domains, such as the use of idea organizers for writing, data analysis tools in social science, and visualization and modelling tools in natural science.
- The ability to provide curriculum developers, researchers, teachers, and even students with detailed information that can be used to improve future learning.

Nevertheless, technology assisted assessment is not without its challenges. According to Alruwais (2018) concerns include:

- Inexperienced students with computers or with the online assessment process.
- Students may need training at the beginning to be familiar with technology assisted assessment.
- Accessibility of computers and internet.
- Poor technical infrastructure development.
- Teachers unfamiliar with technology.
- Teachers may need training to be confident at using technology assisted assessment

However, research suggests the use of technology for assessment is evolving and that teachers are moving toward a deeper understanding of what it means to use technology effectively with students (Yin et al., 2015).

A distinguishing characteristic of formative assessment is the provision of feedback and correctives at each stage in the teaching and learning process. High quality feedback is a key part of the learning process and an opportunity to provide the student an additional learning opportunity. Computer-based assessments that can provide immediate student feedback has the potential to offer new forms of teaching and learning.

Technology assisted assessment systems that allow teachers to quickly collect and analyse student answers to knowledge questions already exist. For example, Clickers, Socrative, Kahoot, Plickers and RecaP have been used to formally assess students for different purposes and in a wide range of disciplines (Elmahdi et al., 2018). All these are generally similar in their core functionality in that both students and teachers can receive immediate feedback regarding students' polling on the clicker questions. Clickers, also called *Classroom Communication System or Audience Response Technology*, has been the most widely reviewed technology to determine whether they raise academic standards in the classroom. To this end, some research has shown a positive impact (Zhu and Urhane, 2018; Chien et al., 2016), while others show little or no gains (Caldwell, 2007; Lasry, 2008), on teaching and learning. However, it has been argued that more studies on integrating technology into assessment is needed and more advanced and convenient technologies should be constantly developed to further push knowledge forward (Yu, 2017). Thus, there is a need to further explore how technology can impact on formative assessment

To address this need, the StudyQuest technologies have been developed built on 5 key features: assessment for learning, well designed feedback, constructive 'nudges', analysis of data, and gamification with incentives. Research by the Learnovate Technology Centre at Trinity College Dublin in 2018 helped inform the design principles on which StudyQuest is based. Thus, it contains a carefully designed, formative feedback for all questions that nudge the student towards the right answer, reinforcing basic knowledge while also helping the student develop conceptual understanding through the use of more advanced questioning to test higher orders of understanding.

The first implementation of StudyQuest (www.JCQuest.ie), which aimed to support Ireland's national Junior Cycle syllabus has been completed successfully. The

Junior Cycle covers the first three years of secondary school. The Junior Cycle examination is held at the end of the Junior Cycle and students normally sit the exam at the age of 15 or 16. The current project, the six-country Erasmus+ study (DALDIS) is aimed at evaluating the effectiveness of this system for Science and Modern Foreign Language learning, across different European contexts.

1 EFFECTIVE PEDAGOGY

Effective pedagogy is defined as “instructional techniques and strategies that enable learning to take place” (Volant, 2018, p.7). It has been argued in the Science educational literature that the traditional pedagogical approach to teaching Science requires a shift from memorization of answers, (geared towards student performance in external examinations), to the opportunity for students to actively engage in the construction and deconstruction of knowledge (Singh and Yaduvanshi, 2015). Against this background it can be argued that there is a need for teachers to adopt a pedagogical approach to support students that goes beyond the rote learning of facts or theories to develop skills like problem solving and critical and reflective thinking. In sum, new theories of the learning process and in particular constructivism (Singh and Yaduvanshi, 2015).

In constructivist theory, the learner constructs knowledge from experience not simply acquired by the act of transmission from the teacher to the student. In this framework learners are active agents who engage in their own knowledge construction when new information is linked to prior knowledge and experience. According to Gilakjani et al., (2013) the construction of knowledge is a dynamic process that requires the active engagement of the learner, who will be responsible for their own learning, while the teacher’s role is to create a learning environment that is interactive, immersive and informative. From a constructivist perspective when technology is used in the classroom, learners use it to:

1. Manipulate data;
2. Intentionally and actively process information;
3. Construct personal and socially shared meaning; and
4. Reflect on the learning process (McClintock, 1992).

In relation to the teaching of Science in Ireland, The *Digital Learning Framework for Secondary Schools (2015-2020)* (DES, 2015a) emphasises that constructivist principles be embedded in all Science teaching and learning practices.

There are several constructivist models available to describe different types of learning outcomes. Blooms model of Taxonomy (1956) is one teaching philosophy solidly grounded in the educational literature and based on a constructivist approach to teaching and learning. Learning, as defined by Bloom is divided into three domains: cognitive, affective and psychometric. The original model of Bloom's taxonomy pertaining to the cognitive domain, incorporated the following categories: knowledge, comprehension, analysis, application, synthesis and evaluation as a set of hierarchical tiers. A revised version of Bloom's taxonomy was introduced in the 1990s which changed the terminology from nouns to verb forms to emphasize thinking as an active process. They are arranged in the chart below in increasing hierarchical order from low to high.

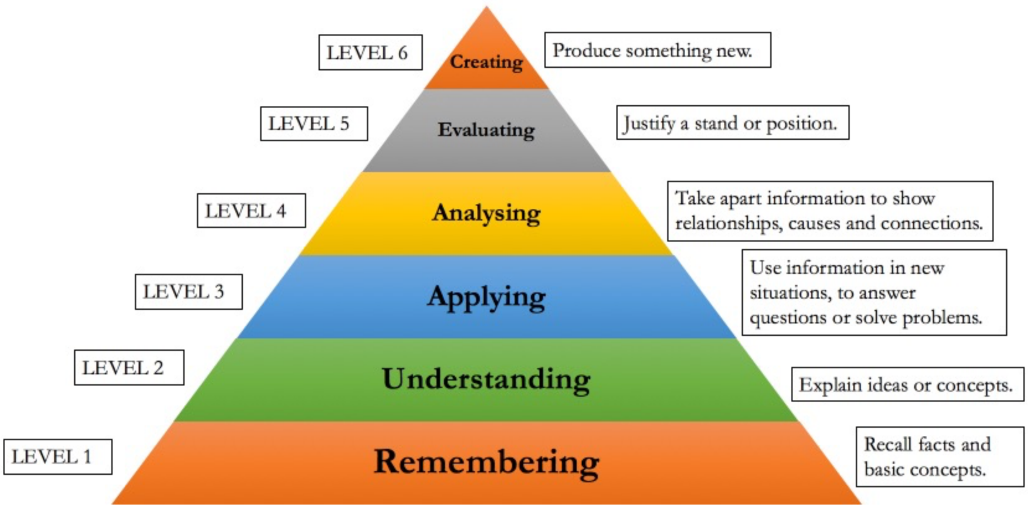

Figure 1: Bloom's taxonomy. (Adapted from Fastiggi, 2019).

The categories are defined as:

Category	**Definition**
Remembering	The learner is able to recall relevant knowledge from long-term memory
Understanding	The learner is able to construct meaning from instructional messages, including oral, written and graphic communication
Applying	The learner carries out or uses a procedure in a given situation
Analysing	Breaking material into constituent parts and determining how the parts relate to one another and to the overall structure and purpose

Evaluating	Making judgments based on criteria and standards
Creating	Putting elements together to form a coherent or functional whole; reorganise elements into a new pattern or structure

Table 1: Categories in Bloom's taxonomy. (Adapted from Anderson & Krathwohl, 2001).

1.1 Bloom's Taxonomy and Formative Assessment

The general learning principles espoused by Bloom can be applied to formative assessment. The following assessment items are examples that could be devised for each category of Blooms taxonomy that would require students to use different levels of thinking:

Knowledge level	**Assessment Items**
Remembering	True or False? Identify, locate, name, select, state, which one? What is……? How many? What are the main……….?
Understanding	Demonstrate, compare, contrast, how would you use? What would result if…...? How would you classify the type of…? What would happen if…….? Explain, Interpret
Applying	What elements would you change.? How would you save energy in your home? What would result if…………? How would you use………..? Construct, differentiate
Analysing	What inference can be made from……….? Which statement is relevant……….? What inference can be made……..? Distinguish, categorise, identify, explain
Evaluating	Which is more important? Do you agree………..? Assess, justify, determine, prioritise, choose
Creating	How many ways can you………….? Arrange, design, How would you construct…………?

Table 2: Assessment items for the knowledge levels in Bloom's taxonomy

The level of difficulty for each question in conjunction with its arrangement in the assessment test has also been investigated. Gronlund (2004) proposes the following guidelines:

- For instructional purposes it is desirable to group together items that measure the same learning outcomes.
- Items should be arranged so that all items of the same type (true/false, multiple choice etc. are grouped together.
- Items should be arranged in order of increasing difficulty.

1.2 Assessment for Learning

Assessment *for* learning is a strategic approach that focuses on what students actually learn from being assessed. This is in contrast to assessment *of* learning designed to judge the work of learners. Assessment *fo*r learning involves teachers understanding their students' progress and how they use this information in order to enhance their teaching practices and further planning of instruction. Using formative assessment enables the teacher to see how the student is evolving as a learner and how to assist them. When a teacher sees learning happening or not happening, they can intervene to alter the direction of learning to attain a specific goal or content. There are many forms of assessment and for different educational purposes, however, as pointed out by Shute (2008, p.1), "..assessment results can and should have important implications for instruction, positively influencing both the teaching and learning sides of the equation."

1.3 Feedback for Learning

Feedback has been identified in many studies on teaching and learning as one of the most powerful influences on student knowledge and achievement. Feedback can be defined as information provided by a teacher regarding aspects of a student's knowledge and understanding (Hattie and Timberely, 2007). Feedback is more effective when it is perceived as low level of threat to self-esteem. Additional learning opportunities should be provided for the strongest students so that they can move even further forward, while teacher's time can be focused on weaker and struggling students. Feedback is most effective when it consists of progress information, creating both a realistic and positive sense of progress to an objective. Hattie and Timperley (2007) and Shute (2009) provide clear guidelines for effective feedback:

- Descriptive feedback is more valuable to the learner than to say an answer is simply right or wrong. The most helpful type of feedback provides specified comments about errors and specific suggestions for improvements.
- Feedback is more effective when it is perceived as a low-level rather than a high-level threat to self-esteem
- Feedback should be targeted at the appropriate level
- Feedback is most effective when it consists of information about progress
- Provides information that leads to greater possibilities for learning
- Multiple choice questions with increasingly complex feedback provided
- Feedback with written comments rather than grades alone can significantly improve test performance
- Give student a second chance to demonstrate success can improve their instruction and help students learn.

According to Shute (2008) good feedback can significantly improve the learning process and outcomes, but only if it is delivered correctly. Shute describes the multiple forms of formative feedback that can be employed to modify thinking or behaviour to increase knowledge, skills, and understanding in some content area or general skill as outlined in the table below:

Type of feedback	Description
No feedback	Refers to conditions where the learner is presented a question and is required to respond, but there is no indication as to the correctness of the learner's response
Verification	It informs the learners about the correctness of their response (e.g., right/wrong or overall percentage correct)

Correct Response	Informs the learner of the correct answer to a specific problem, with no additional information
Try again	Informs the learner about an incorrect response and allows the learner one or more attempts to answer it
Error Flagging	Error flagging highlights errors in a solution, without giving correct answer
Elaborated	Refers to the provision of an explanation about why a specific response was correct or not and may allow the learner to review part of the instruction. It may or may not present the correct answer
Attribute Isolation	Elaborated feedback that presents information addressing central attributes of the target concepts or skill being studied
Topic Contingent	Elaborated feedback that focuses on the learner's specific response. It may describe why the incorrect answer is wrong and why the correct answer is correct
Response Contingent	Elaborated feedback that focuses on the learner's specific response. It may describe why the incorrect answer is wrong and why the correct answer is correct
Hints/cues/prompts	Elaborated feedback guiding the learner in the right direction e.g., strategic hint on what to do next or a worked example or demonstration. Avoids explicitly presenting the correct answer
Bugs/misconceptions	Elaborated feedback that provides information about the learner's specific errors or misconceptions (e.g., what is wrong and why)
Informative Tutoring	The most elaborated feedback. This presents verification feedback, error flagging and strategic hints on how to proceed. The correct answer is not usually provided

Table 3: Types of formative feedback. (Adapted from Shute, 2008).

In addition, several researchers contend that some types of feedback are significantly more effective and better than others when:

- Feedback provides specific details of how to improve the answer, as this is more beneficial than simply verifying whether the answer is correct or not (Bangert-Drowns et al., 1991)

- It provides specific details expressed in a language the student can understand as it requires more effort to understand the information behind unspecific feedback (Nicol, 2010)
- The feedback is provided immediately (Particularly for low achieving students) as immediate error correction can result in faster rates of acquisition (Park Woolf, 2009)
- Provides the learner with two types of information: verification (whether the answer is right or not) and elaboration (information) that addresses the topic, the response, gives guidance, provides information about the correct answer or directs the learner to the relevant part of the textbook where the answer exists. (Shute, 2008).
- It is contextualised – framed with reference to the learning outcomes and /or assessment criteria (Nicol, 2010)
- It provides an explanation of the answer as correct and why the alternative is incorrect as a learner may have chosen the correct answer but not actually have understood why it is correct it (Sheard & Chambers 2014)
- It allows the student work independently and at their own pace privately encouraging feelings of self-esteem and self-efficacy (Mahon, 2012)

On the other hand, feedback produces **negative effects on learning** when it:

- Is construed as critical
- Lacks information to improve performance
- Is too vague and lacking in detail

- Focuses only on the negative and areas of weaknesses
- Indicates student's standing relative to peers (via scores or grades)

Consistency and Validity

Other important aspects of assessment are validity and consistency. Consistency refers to the items within the assessment and whether the language used on a learner's performance is consistent and reliable on two comparable tasks. Validity, on the other hand refers to the extent to which the assessment accurately measures what it is supposed to measure at the appropriate level. This is particularly important as teachers can make decisions based on assessment results in order to adapt their educational practices for the purpose of maximizing learning results.

Feedback Complexity and Length

An element to feedback that is also important to consider is the length and complexity of the information. According to Duss (2018), "..if feedback is too long or too complicated, many learners will simply not pay attention to it, rendering it useless. Lengthy feedback can also diffuse or dilute the message".

1.3.1 A Framework for Feedback: Hattie and Timperley

To assist in understanding the effects and purpose of feedback, Hattie and Timperley (2007) argue that effective feedback must meet three criteria in order to "reduce discrepancies between current understanding/performance and a desired goal" (Hattie & Timperley, 2007, p.87). The figure below presents a framework in which feedback can be considered. The authors also provide a four-level framework to guide the focus and influence the effectiveness of feedback corresponding to the phases of learning: from novice, through proficient, to competent:

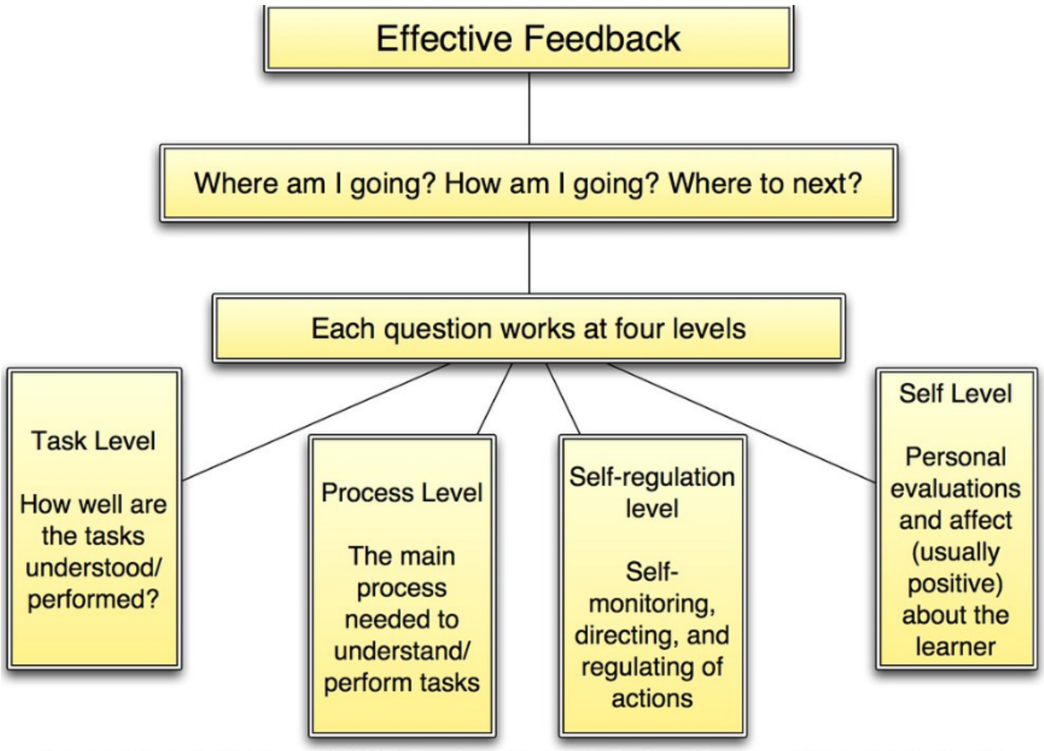

Figure 2: Framework for effective feedback (Hattie & Timperely, 2007)

The three criteria can be described as follows:

- **Where am I going**? (Feed up). This refers to the aims of the lesson that the teacher needs to communicate to the class and for the student to understand what is expected from them, hence the importance of the establishment of learning outcomes. Feedback at this level highlights whether the answer is correct or incorrect

- **How am I going?** (Feedback). Answering this question involves a teacher providing information relative to a task or performance goal, often in relation to some expected standard, to prior performance, and/or to success or failure on a specific part of the task. This kind of feedback gives information about progress and how to proceed.
- **Where to next?** (Feed forward) Can be addresses by providing opportunities to the student for further learning. This could include, for example, more information about what is and what is not understood.

The four-level feedback is:

1. **Task and product level**. includes simple feedback about whether the task is correct or incorrect. It may also include further information that takes into account the student's current understanding and ability level. The teacher should move to the next level feedback when the student has sufficient confidence at the task level.
2. **Process level**: This kind of feedback can be aimed at the process used to create, understand and complete a task. For example, a teacher may help to provide connections between ideas, or cue to the learner different strategies to complete the task.
3. **Self-regulation/conditional level**: Feedback to students can be focused at improving their ability to monitor their own learning and progress and engage further on a task.
4. **Self-level: providing praise**, but not in such a way that it dilutes the power of feedback

2 EUROPEAN PERSPECTIVE ON THE EVALUATION AND ASSESSMENT OF SCIENCE

In 2009, the Organisation for Economic Co-operation and Development report (OECD) Education Policy Committee conducted a wide-ranging review of European evaluation and assessment policies, the OECD (2009) *Review on Evaluation and Assessment Frameworks for Improving School Outcomes*. Its objective was "..to provide policy advice to countries on how evaluation and assessment arrangements can be embedded within a consistent framework that can bring about real gains in performance across the school system." (OECD, 2013, p.1).

Several factors are driving the increased use of evaluation and assessment, including:

- An increased demand for effectiveness, equity and quality in education to meet economic and social challenges
- A trend in education towards greater school autonomy, which is fuelling a need to monitor how schools are doing.
- Improvements in information technology, which allow for the development of both large-scale and individualised student assessment and facilitate the sharing and management of data.
- Greater reliance on evaluation results for evidence-based decision making.

Most European countries now see evaluation and assessment as playing a central strategic role, and are expanding their use (OECD, 2013). This is reflected in efforts to transform their educational systems using a range of approaches for evaluation and assessment at all levels, from the student to the school system itself. According to the Danish Technological Institute (2015), STEM (science, technology, engineering, and mathematics) subjects in particular have received growing attention in European education policy discourses during the past decade for a number of reasons:

- STEM skills are associated with advanced technical skills, which are seen as strong drivers for technology and knowledge-driven growth and productivity gains in high-tech sectors, including ICT services.

- Due to demographic developments, there will be a high replacement demand for highly-skilled professionals working in STEM-related occupations in the coming years. This has led to concerns that Europe could lack an adequate supply of STEM skills to enable its future economic development (European Parliament - Committee on Employment and Social Affairs, 2013).
- Europe has a comparatively poor record of attracting top-level STEM professionals from abroad
- Concerns about the quantity and also at times the quality of STEM graduates

2.1 Trends in Science Education and Assessment Practices for 21st Century Learning

The European Commission responsible for policy has recognised Science education as a key agenda for better equipping students with the knowledge, skills and competencies they need to participate fully and actively in an increasing scientific and technological world. The EU member states have set a benchmark to reduce the proportion of 15-year-olds with low achievement in science to less than 15 % by 2020 (European Policy Cooperation ET 2020 Framework). To achieve this ambition, there is to be a transition from curriculum directed to a competence-guided educational system. The focus is now on output-oriented and student-centred construction (Mathelitsch, 2013). Aspects of competence in Science is defined by the EU in terms of knowledge and skills and indicates what the student should know and understand. To illustrate, students should:

- Have the ability to evaluate scientific and numerical information on the basis of its sources and the methods used to generate it.
- Have the capacity to evaluate scientific arguments based on evidence and to apply conclusions from such arguments in an appropriate manner.

The intersection of Science education and 21st Century skills has been recognized as a major goal of Science education. According to (Turiman et al., 2012), 21st Century skills can be cultivated through scientific literacy and Science process. Science process refers to the process of doing Science. For example, observation, communication, classification, measurement, inference and Prediction. Scientific literacy on the other hand is defined as "..the knowledge and understanding of the scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (Turiman et al., 2012, p. 112).

Özdem et al. (2010, p.206) state that the characteristics of a scientifically literate individual is one that understands the:

- Basic concepts of Science
- Nature of Science
- Ethics that control the scientist in his/her work
- Interrelationships of Science and society
- Interrelationships of Science and the humanities
- Differences between Science and technology

In line with developments from learning scientific facts to learning outcomes it is important to develop assessment frameworks that addresses what the learner knows, understands, and is able to do with what they learn. Recommendations from the *Assessment Practices for 21st Century Learning: Review of Evidence* (Serova et al, 2017) to improve assessment practices to measure and support students' acquisition of key competences and transversal skills include the following:

- Policy-makers and schools should promote and employ an integrated approach towards classroom assessment
- Define key competences in terms of detailed and concrete learning outcomes is necessary for consistent assessment practices
- Portfolios, holistic scoring rubrics and formative feedback can be helpful for formulating goals, monitoring student progress and assess broad competences. The systematic development of these methods should be supported.
- Assessment practices need to document learners' competences and help develop them informing teachers' practices and curricula focus
- The use of ICT in assessment allows to deliver traditional assessment faster and more effectively and at the same time offers opportunities to change the way competences are assessed

- Using technology-based assessments for formative assessment purposes should be accompanied by effective feedback and scaffolding mechanisms

2.2 The Revised Irish Junior Cycle Curriculum for Science

The design of the StudyQuest solution which DALDIS will use and evaluate has been influenced by Ireland's Revised Junior Cycle Curriculum for students aged 12-15. The materials and work completed to-date are designed to support science and modern-foreign-language teaching and learning for this curriculum. This revised curriculum is based on international best practice and was introduced on a phased basis in September 2014. The new junior cycle features revised subjects and short courses with a focus on literacy, numeracy and key skills, and new approaches of assessment and reporting.

The development of Science education in Irish schools has undergone a significant change in the last decade. The rhetoric for change at Junior cycle level emerged following a report by the Programme for International Student Assessment (PISA) published in 2013 that showed that the performance of Irish students had changed little in international comparative studies assessing scientific literacy since previous PISA Science assessments in 2000 and 2003. The absence of any discernible improvement suggested that what was being offered as Junior Certificate Science education to Irish students was falling short of what students needed. Attention was also drawn to the 2007 Relevance of Science Education (on how 15-year old learners relate to science and technology) (ROSE) project. Many students did not see the relevance of the science they learnt in school to their everyday lives and they lacked awareness of the links between science and their world. Furthermore, the Interdepartmental Committee on Science, Technology and Innovation (2015) has stated:

> *"Ireland's future growth depends on innovation and future innovation depends on people. This requires action at all levels, from encouraging greater engagement with science, technology, engineering and mathematics at primary level to ensuring the necessary supports for researchers at postdoctoral and Principal Investigator levels"*
>
> (2015, p.10).

In these contexts, following extensive consultation with a wide variety of stakeholders in Science education, the National Council for Curriculum and Assessment (NCCA, 2015), a body that advises the Irish Department of Education, endorsed the recommendations and the outcome resulted in a new Science specification for Junior Cycle.

2.2.1 Overview of the New Junior Cycle Science Curriculum

The new Junior Cycle Science curriculum was introduced to 1st year students (aged 12-13) in Ireland in September 2016. The specification for Junior Cycle Science over three years focuses on the development of students' knowledge of, and about, science through the unifying strand, Nature of science, and the four contextual strands: Physical world, Chemical world, Biological world, and Earth and space. Central to the *Framework for Junior Cycle* (DES, 2015b) is the integration of the 24 Statements of Learning of which the following are linked to the Junior Science cycle.

Statements of Learning	
SOL 9.	The student understands the origins and impacts of social, economic, and environmental aspects of the world around him/her
SOL 10.	The student has the awareness, knowledge, skills, values and motivation to live sustainably
SOL 13.	The student understands the importance of food and diet in making healthy lifestyle choices

SOL 15.	The student recognises the potential use of mathematical knowledge, skills and understanding in all areas of learning
SOL 16.	The student describes, illustrates, interprets, predicts and explains patterns and relationships
SOL 17.	The student devises and evaluates strategies for investigating and solving problems using mathematical knowledge, reasoning and skills
SOL 18.	The student observes and evaluates empirical events and processes and draws valid deductions and conclusions
SOL 19.	The student values the role and contribution of science and technology to society, and their personal, social and global importance.

Table 4: Junior science cycle Statements of Learning (DES, 2015b)

In addition, teachers are encouraged to embed the following 8 key skills and 8 principles in their course planning and Statements of Learning:

2.2.2 Junior Cycle Key Skills

1. Managing Myself
2. Staying Well
3. Communicating
4. Being Creative
5. Being literate
6. Being numerate
7. Working with Others
8. Managing Information and Thinking.

Figure 3: Junior cycle key skills (NCCA, 2015)

2.2.3 Junior Cycle Key Principles

1. Quality
2. Creativity and Innovation
3. Engagement and Participation
4. Continuity and development
5. Wellbeing
6. Choice and Flexibility
7. Inclusive Education
8. Learning to learn

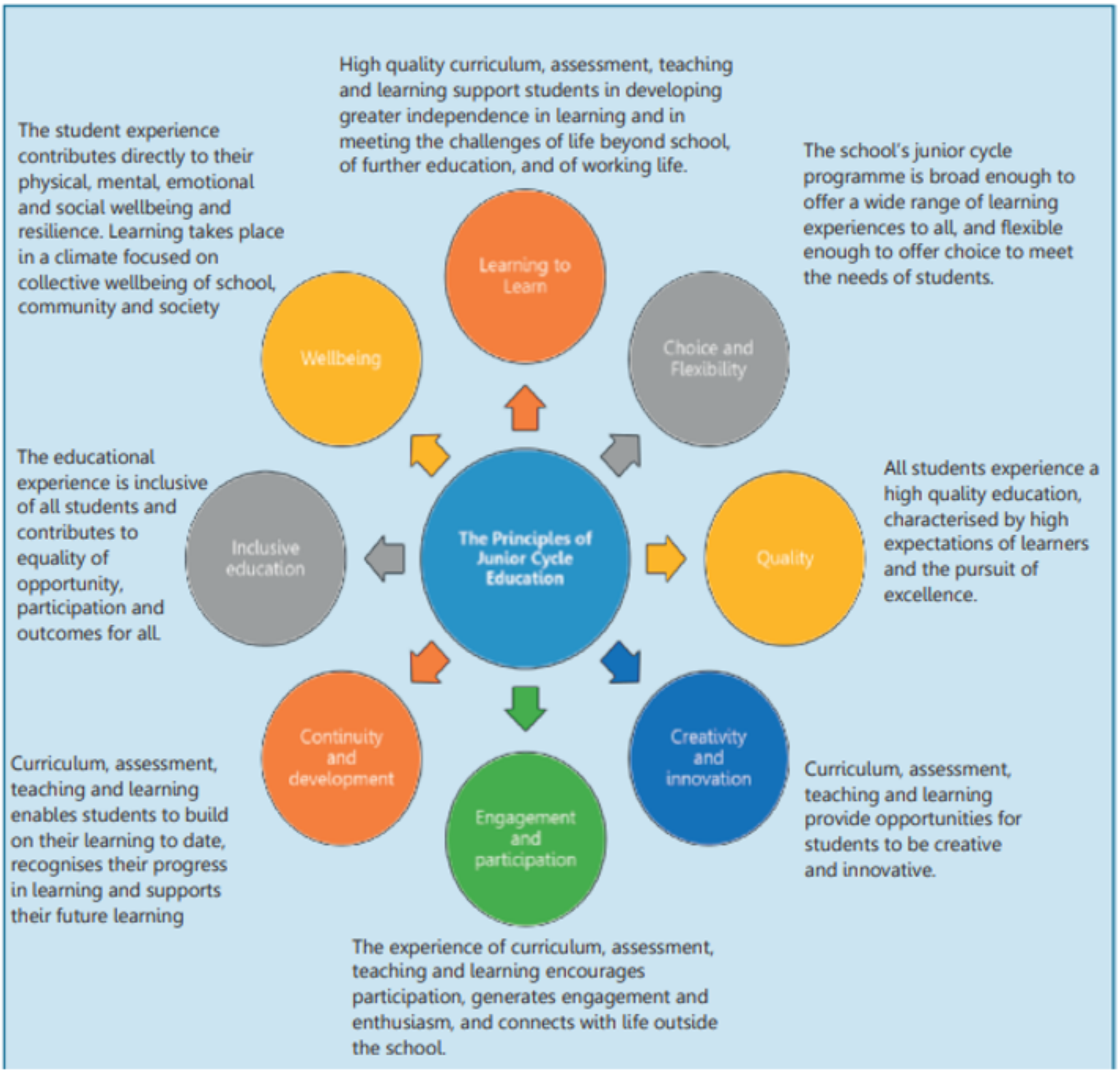

Figure 4: Junior cycle key principles (NCCA, 2015).

2.2.4 Assessment for the Revised Junior Cycle Science

The most significant difference in the revised Junior Cycle is in the broadening of the approach to assessment. While there is still a formal Science examination (constructed from the NCCA framework for teaching and learning Science, 2005) for which the Junior Cycle Profile of Achievement (JCPA) is awarded to students at the end of the three-year cycle, teachers also use a wide variety of assessment methods for formative purposes during the learning period and for summative purposes at the end of a learning period. Along with end of term exams, other forms of assessment students undertake over the three years of Junior cycle are classroom-based assessments (CBAs). The rationale behind including CBAs was to reduce the focus from the final examination and encourage an inquiry-based learning approach to Junior Cycle Science. The first CBA is done in form 2 (year 8) and is an extended experimental investigation (EEI). The second is done in form 3 (year 9) and is a research essay. Students then submit a reflection on the third-year research essay. CBA's are marked by teachers along with a Subject Learning and Assessment Review (SLAR) consultation process in the school. The reflection on the third-year research essay is marked by the State Examining Commission (SEC) and it is worth 10% of the overall exam mark.

2.3 Denmark: The school system

The Danish Folkeskole is a comprehensive school system covering both primary and lower secondary education. The duration of compulsory primary and lower secondary education is 10 years from age 6 to 16-17. Compulsory education commences on 1st August of the calendar year of a child's 6th birthday and terminates on 31st July of the year in which the pupil finishes 9th grade or alternatively when the pupil turns 17 years old (Eurydice, 2018).

The primary and lower secondary education institutions comprise:

- Municipal basic schools (Folkeskoler)
- Private elementary schools
- Continuation Schools-Alternative provision for pupils in the age range of 14 to 16.

The low scores and weak performance of Science in the PISA reports across the years have resulted in significant changes in the Danish compulsory school system (the *Folk-eskole*). See performance trends in Science below.

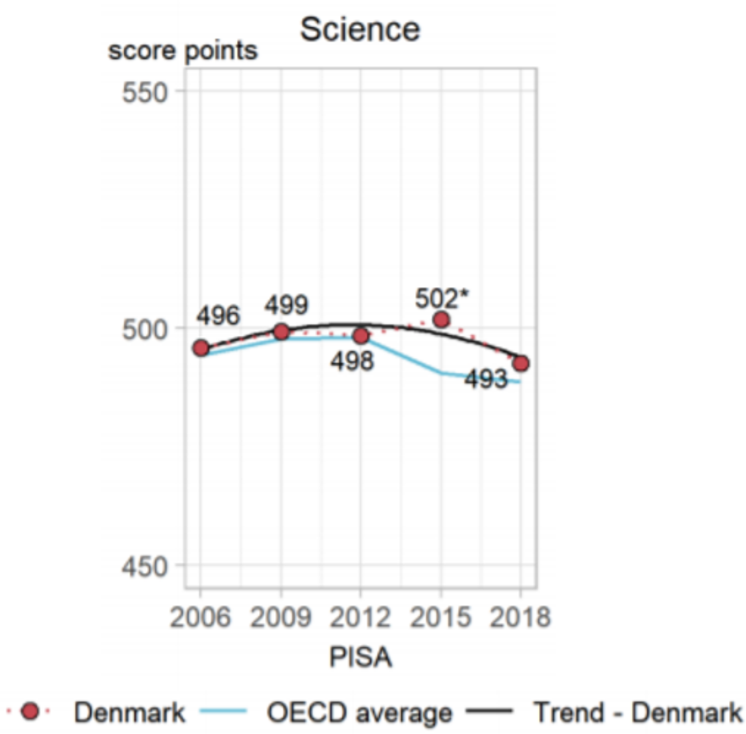

Figure 5: Performance trends in science for Denmark (OECD, 2018).

To address Danish students' modest performance in international comparisons, the Danish Government has introduced several educational reforms to strengthen student assessment, school evaluation and system evaluation. As part of this process from 2010 a range of compulsory national tests have been introduced. For example, Biology, Physics and Chemistry are examined in 8th form. The tests are digital and adaptive, meaning that they adapted to the individual student. Schools are also required to conduct regular evaluations of the students' learning outcomes based on the Common Objectives that schools are obligated to follow. Private schools are not required to use the national student Common Objectives or national tests.

Denmark recognises STEM through strong investment by the Ministry of Education with the National Natural Science Strategy and the Technology Pact which aims to have an additional 20% of students complete educational programmes in the STEM field (Ministry of Industry, Business and Financial Affairs, 2018).

The overall goal of the strategy is to increase students' interest in the STEM-disciplines. This includes:

- Stronger science skills at all class levels
- Improved academic standards for Science teachers
- Development of new procedures to maintain science interest among talented students

According to the OECD the strengths in Denmark's policy towards assessment includes the following:

- Strong potential for formative assessment practice and availability of national assessment resources and supports
- A good mix of teacher judgement and standard examinations in the final diploma for compulsory education
- National tests provide rapid feedback to educators on student performance against the Common Objectives
- National initiatives have stimulated teacher teamwork and teacher-parent co-operation

2.4 Greece: The school system

In Greece, lower secondary education (gymnasium) lasts three years which cover ages 12-15 and completes the compulsory education cycle. Students successfully completing the gymnasium programme receive the lower secondary school-leaving certificate which enables them to enter upper secondary school without an entrance exam. Greece has little external assessment of learning or external evaluation of schools and teaching or any comparative mechanism of quality assurance (except for its participation in PISA (OECD, 2018). In comparison to other educational systems, Greece has lower than average achievements in Science performance on PISA with results declining gradually since 2006 by an average of 5. See performance trends below:

Figure 6: Performance trends in science for Greece (OECD, 2018).

The reform of the Greek educational system is one of the central goals of the policies stated in *Greece: A Growth Strategy for the Future* (2018) aimed at improving the effectiveness of education. The main objectives are the modernization of educational structures, the improvement of educational outcomes and the integration of graduates into the labour market. Notable reforms include:

- Promoting the acquisition of skills and competences by: addressing underachievement in maths, science and literacy through effective and innovative teaching and assessment
- Promoting entrepreneurship education; fostering critical thinking especially through teaching STEM (Science, Technology, Engineering and Mathematics) related courses, as well as science in environmental and or cultural context.

Pupil assessment is regarded as an integral part of the on-going pedagogical process (UNESCO-IBE, 2011). The assessment is based on daily oral assessment, the student's participation in the teaching-learning process, short written tests and hour-long compulsory written tests which are given without notice in the first two terms.

2.5 Poland: The school system

The Polish education system has gradually introduced a new structure to be completed by 2023/24. In the new school system, the 8-year primary school (szkoła podstawowa) which covers both International Standard Classification of Education (ISCED) 1 and 2 is attended by children aged 7 to 15 years. Subsequently, students can continue education in secondary schools or in other settings, such as practical vocational training at a workplace, combined with theoretical training, or vocational qualification courses (Eurydice, 2018). External summative examinations are conducted at the end of compulsory education.

When it comes to assessment practices in Poland the performance and progress of students are assessed regularly by teachers throughout the school year. It is primarily formative assessment as the focus is on:

1. Informing pupils on the level of their learning achievements and behaviour, and their progress in this respect;
2. Supporting pupils in learning by providing feedback to them on where they have performed well and how they should continue to learn;
3. Supporting pupils in the individual planning of their development;
4. Motivating pupils to make further progress in learning and behaviour;
5. Providing parents (legal guardians) and teachers with information on pupils' progress or learning difficulties, behaviour and special talents;
6. Enabling teachers to improve organisational approaches and methods used in their educational activities (Eurydice, 2018).

Recent reforms have led to rapid improvements in Poland's educational performance. Poland remains above the OECD average in Science with the PISA 2018 performance about 10 points higher than in 2015. See performance trends below:

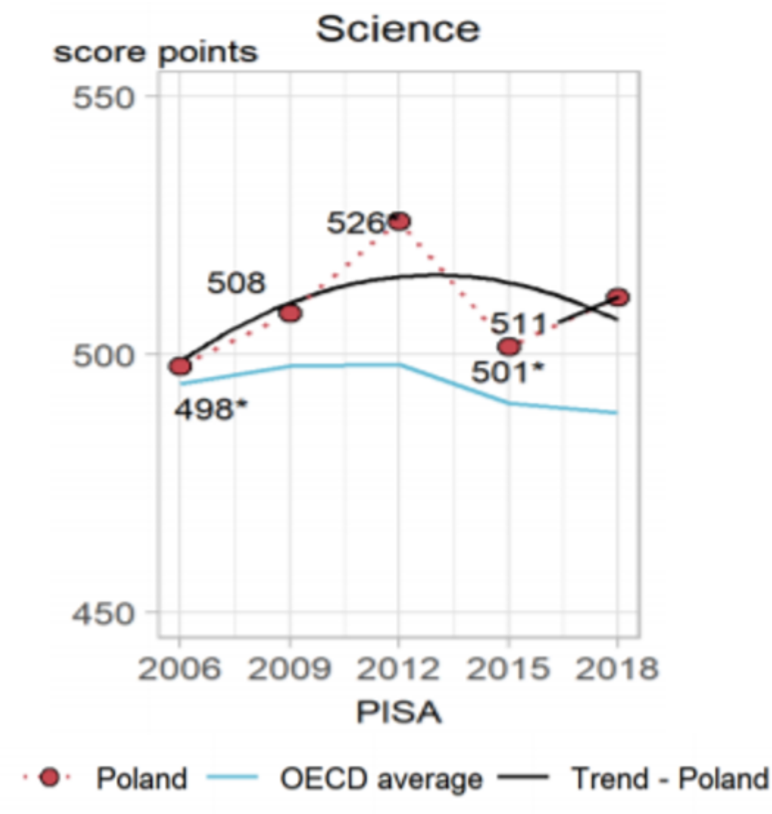

Figure 7: Performance trends in science for Poland (OECD, 2018).

2.6 Turkey: The school system

There are many different types of high schools in Turkey which includes Anatolian High School, School of Social Sciences and general High Schools (Lycees) conducting vocational and technical programmes but the majority are enrolled in 'general type high schools' (Taser, 2013). The implementation of education in STEM disciplines varies according to the school level, school type, and teacher characteristics, respective to each school level and type (Alacaci & Erbaş, 2010). The PISA 2018 report recently published indicates that Turkish students scored lower than the OECD average in Science. This was not significantly different from the results obtained in 2009 or 2012.

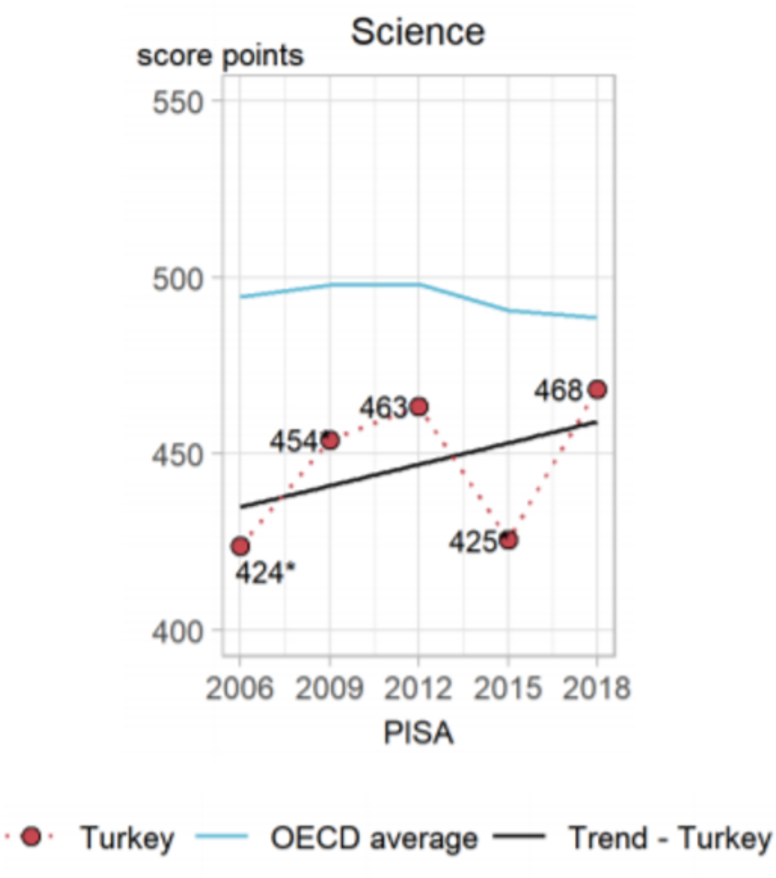

Figure 8: Performance trends in science for Turkey (OECD, 2018).

Like other European countries Turkey has given distinct consideration and importance to the teaching of Science (Turiman & Bonnstetter, 2007). The new Science curriculum was gradually implemented from 2017-2018 in order to increase the quality of Science education in Turkey.

The learning objectives for Science include the following:

- To enable students develop themselves to become scientifically literate
- To equip students to learn and understand the natural world and to enjoy living with its richness
- To encourage students to develop curiosity in the scientific and technological developments and events around us
- To associate and understand the relationship between science, technology society and the environment
- To enable students to structure new knowledge by reading, searching and discussion
- To help students develop knowledge, curiosity, attitudes and experience about Science and Science-related professions or jobs
- To enable students to learn and follow the changing nature of knowledge and jobs, so as to update their knowledge and skills by themselves in their profession

Whereas in the old curriculum only general objectives for each Science subject were given, in the new curriculum specific learning outcomes are included similar to the curriculum in Ireland.

Examples of Learning Outcomes expected

Physics Grade 9 Unit 1. It is expected that in relation to classification of matter, the student: Explains that mass and volume are common features of matter**.** Classifies matter based on the state

Chemistry Grade 10 Unit. 1 It is expected that in relation to chemical entities, the student: Differentiates among atom, molecule, ion and radicals

Biology Grade 11. It is expected that in relation to the structure of plants, the student: Shows the basic structure of a fanerogam on a diagram. States the functions of a body and gives examples of main types of plant body

Assessment practices in Turkey includes sample questions, problem solving exercises, concept maps, self-peer appraisal (Ayas, 2012).

3 TECHNOLOGY ASSISTED ASSESSMENT

According to Scalise and Gifford (2006) any interaction with a user such as questions, tasks, quizzes can be considered an assessment item from which data can be collected with the intention of making an inference about the respondent.

The most common type of items in technology assisted assessments are the standard multiple-choice question which offers a set of responses from which a student is expected to make a choice. They are considered popular as they allow for consistent and objective grading. In addition, multiple-choice testing has been shown to positively enhance retention of the material and improves access to otherwise difficult-to-retrieve knowledge tested by those questions (Little, 2018). It has also been reported that multiple choice questions can bolster students' confidence and self-esteem by ensuring that students are not marked down for poor spelling, grammar or writing skills (Douglas et al., 2012).

However, while multiple choice questions have potential benefits, some issues are raised about their utility in helping students make progress in their learning. It has been argued that multiple-choice testing can be limiting and encourages poor attitudes toward learning and comprehension of the topic (Ozuru, et al., 2013). To optimise learning different formats of multiple-choice questions can also be used to assist in assessing deeper thinking and understanding. One example is the ordered multiple-choice testing format (Briggs et al., 2006) where each answer choice represents a different developmental level of understanding. Thus, interpreting item responses provides instructors with a better grasp of how deeply a student understands the content. Another method to try to ensure that students' true understanding of the topic is assessed (rather than random guessing) is to conduct confidence testing where students are required to report level of confidence in knowing the answer prior to selecting (or even being able to view with online testing) answer choices. Scoring is then based on a combination of whether or not students selected the correct answer, as well as how confident they were in their response (Davies, 2002). Yet another approach that is argued to reveal a student's better understanding is to include open-response or short-answer questions, where students must write or create an answer or explanation using their own words (Haudek et al., 2007).

Design of a Technology-Based Assessment System

From a design point of view, the development of an intuitive user interface is crucial, as it must take into account how information is visually presented to a broad range of users and digital ability (Galitz, 2007) If a screen's layout and a systems navigation is confusing users will have great difficulty in accessing the content and may be discouraged from using the site. Simple visual and spatial representation in design layout is easier for users to retain operational concepts. (Galitz, 2007). The researchers also suggest that pictorial representations of a topic are more natural and advantageous because the human mind has a powerful image memory. According to Rohrer and Pashler (2012) students learn more from combining verbal and visual information than from verbal information alone regardless of learning style. In addition, visual representations are a powerful tool, because they help to make the unseen seen and the complex simple (Quillin and Thomas, 2015). Moreover, this “dual coding" helps teachers address classroom diversity, preferences in learning style, and different ways of "knowing.” (Johnson, 2015, p. 30).

Data Collection

Technology allows large sets of data that can help teachers effectively manage, monitor and record student progress. If the class is not progressing adequately, the teacher can use the technology to have immediate feedback on the students' progress. Thus, they have an awareness of their students' progress and understanding during the learning process rather than at the end. This in turn allows the teacher to make timely decisions and reflect on and adapt their pedagogical strategies when using digital technologies to personalise and facilitate pupils' ownership of their learning (Digital Learning Framework, 2015).

4 STUDYQUEST: IMPLEMENTING DIGITAL ASSESSMENT FOR LEARNING

StudyQuest is a digital assessment tool designed to support, facilitate and enhance current teaching and learning of Science to be delivered in five European countries. This on-line resource is aimed at providing instant access to a range of up-to date Science learning materials. It is based on Ireland's Junior Cycle Specifications for Science as this provides a framework that is compatible with the PISA guidelines for the teaching of Science.

Hattie and Timperley's (2007) framework serves as the conceptual framework for the system. Their model was selected as their systematic meta-analyses incorporated 196 studies and nearly 7000 effect sizes and concluded that feedback had a powerful effect on learning outcomes. In addition, the model ensures that all learners have the opportunity to make sense of, and modify their knowledge based on feedback until competency is achieved.

To put this framework into practice the essential characteristics, features and affordances of the StudyQuest system are described in the sections below.

4.1 Usability of StudyQuest

Usability refers to the ease of use or access, as this will determine any systems usability. Applying the findings from the literature on interface design, the Home page has a clean uncluttered look with 'tabs' for the teacher or student and graphic representations (Galitz, 2007) of the subject and topic area the user may be interested in.

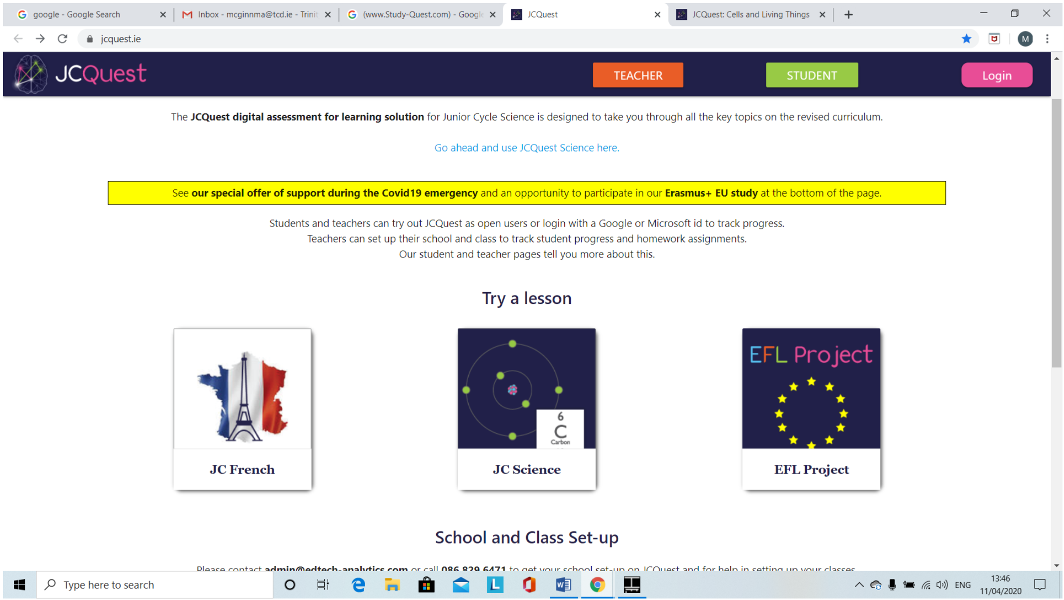

Figure 9: The StudyQuest home page

The learner can then navigate to the desired module presented with visual representations of the topic to facilitate navigation and searching of information by users (Galitz, 2007).

For examples of the modules covered see the figure below:

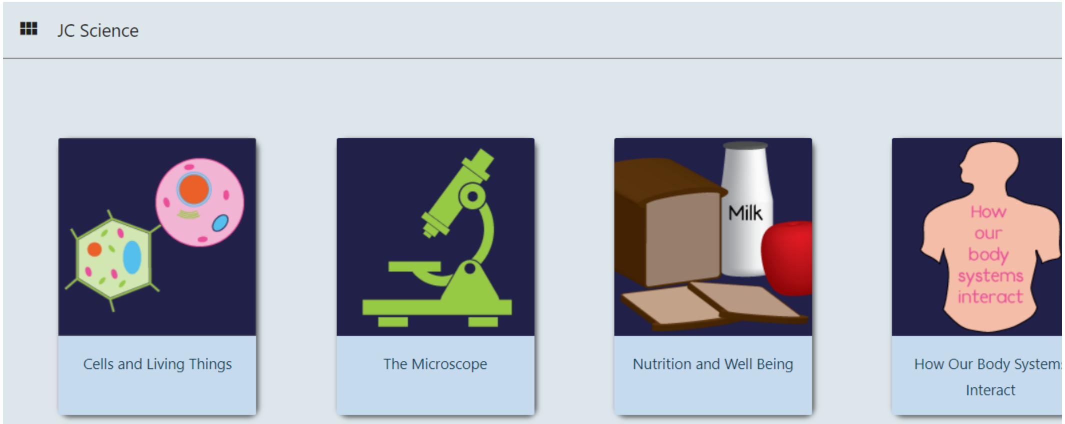

Figure 10: Examples of StudyQuest modules

Having chosen a topic, for example 'Cells and Living Things' in the centre of the screen there is a list of the Learning Outcomes. This corresponds to Hattie and Timperley's (2007) first task level 'Where am I going' recommendations that places the establishment of learning outcomes as an important first step in expressing what the student will know, understand and be able to do on completion of the process.

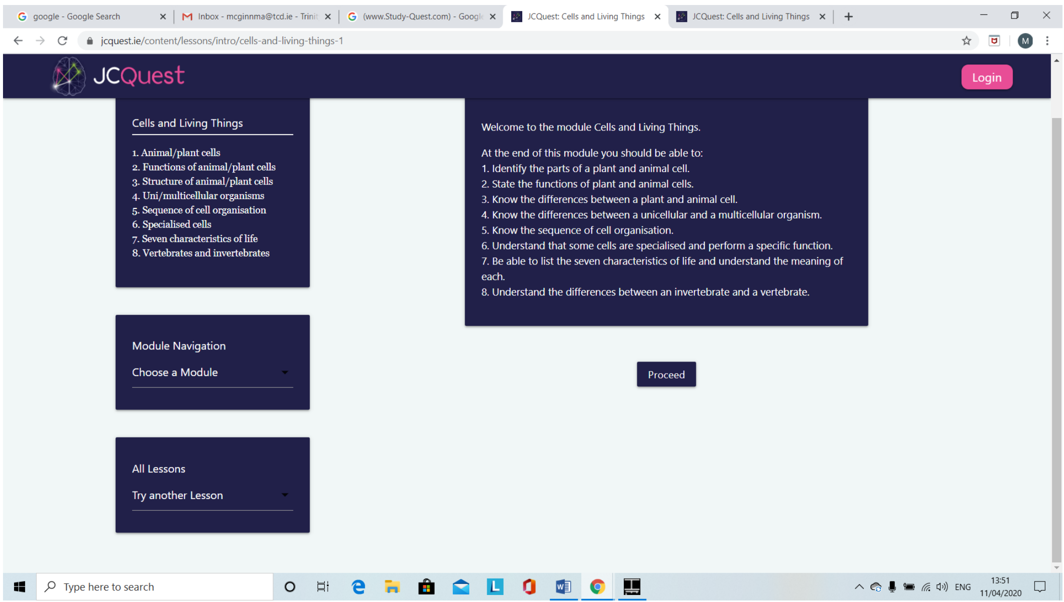

Figure 11: Example of StudyQuest learning objectives

By clicking on the navigation panel on the left of the screen, a multiple-choice question with 4 options is presented from which the learner can choose. A graphical illustration of the question is provided to the learner to facilitate understanding and enhance knowledge transfer/retention.

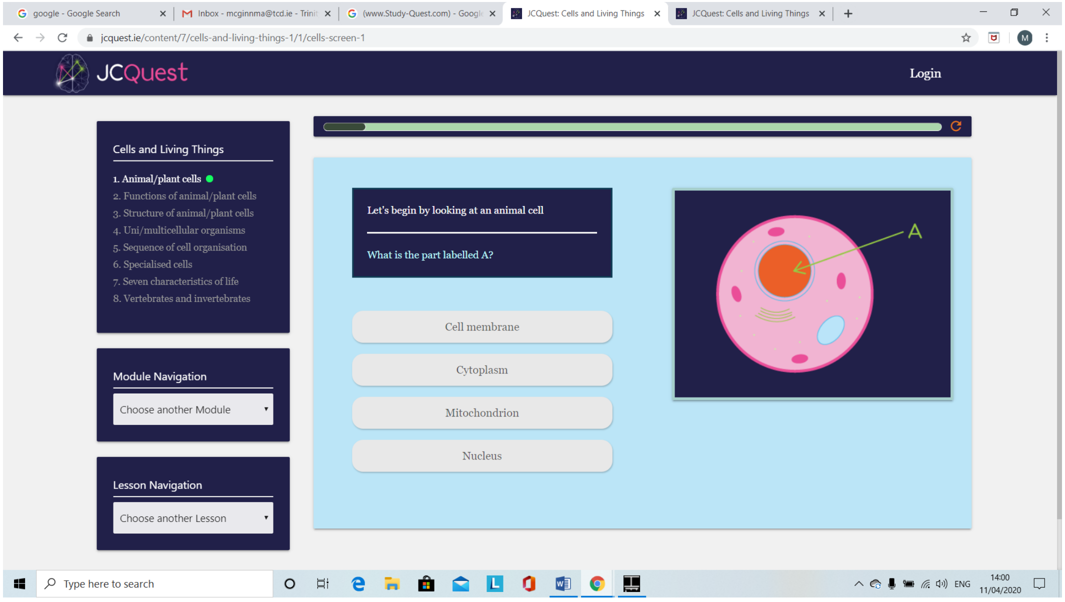

Figure 12: Example of StudyQuest multiple-choice questions

When the learner chooses one of the options the system provides the learner with immediate elaborated feedback (Park Woolf, 2009, Shute, 2008) and expressed in a language that can be understood (Nicol, 2010) as to whether the answer is correct or not and in addition, answering Hattie and Timperley's (2007) task feedback 'How am I going'.

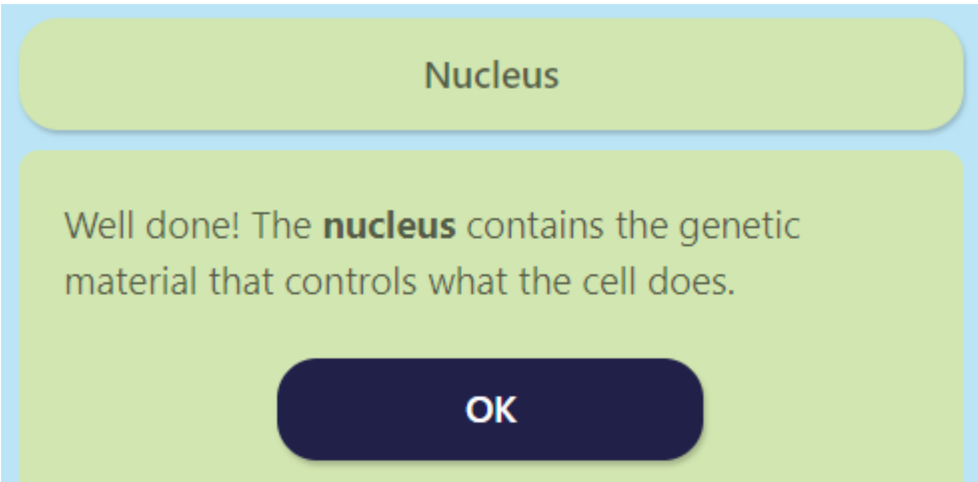

Figure 13: Example of a correct answer feedback in StudyQuest

However, if the answer is incorrect, the learner is asked to try again, while at the same time provided with guidance towards the correct answer. Within the StudyQuest system, as proposed by (Gusky, 2007) the learner has several opportunities for additional attempts to achieve the correct answer. This allows learners to be "motivated, enabled and actively engaged in a successful learning process" (Sheard & Chambers, 2014, p.15)

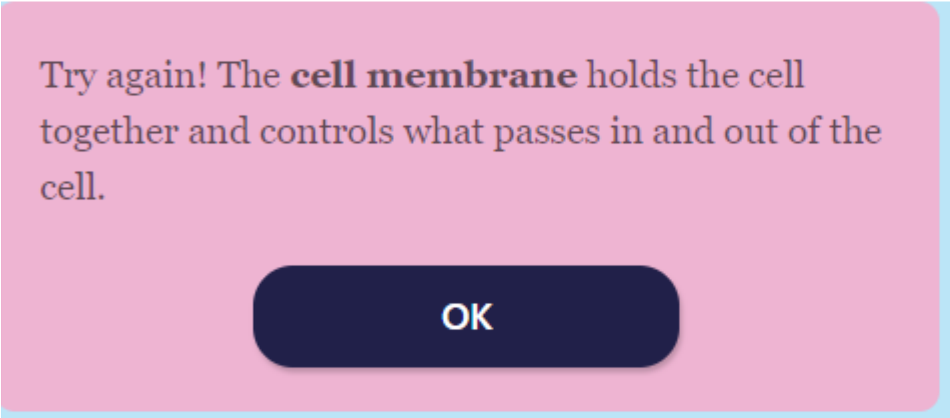

Figure 14: Example of an incorrect answer feedback in StudyQuest

An interesting feature of the system is that the learner cannot proceed to the next level until he/she has responded with the correct answer.

According to Hattie and Timperley (2007) simply providing feedback is not enough and the next step must be 'Where to next'. This information can offer guidance or could include, for example, more information about what is and what is not understood. In the example below on the function of 'The microscope' if the learner chooses the incorrect answer, they are asked to try again while at the same time is provided with more information or 'nudge' towards the correct answer.

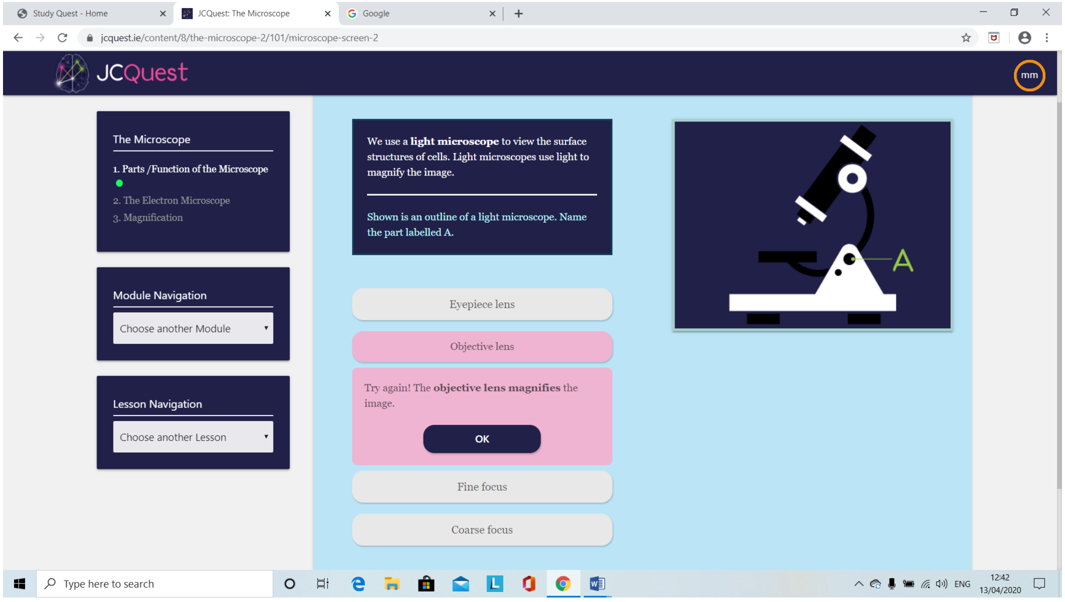

Figure 15: Example of 'nudges' to the correct answer in StudyQuest

When the user provides the right answer, it is contextualised and framed with reference to the learning outcomes (Nicol, 2010). In the example below, the user is provided with feedback praise (Hattie and Timperley, 2007) "Well done" and also directing the learner to an aspect of the learning outcomes that they have achieved thus developing self-efficacy and confidence which in turns leads to further learning

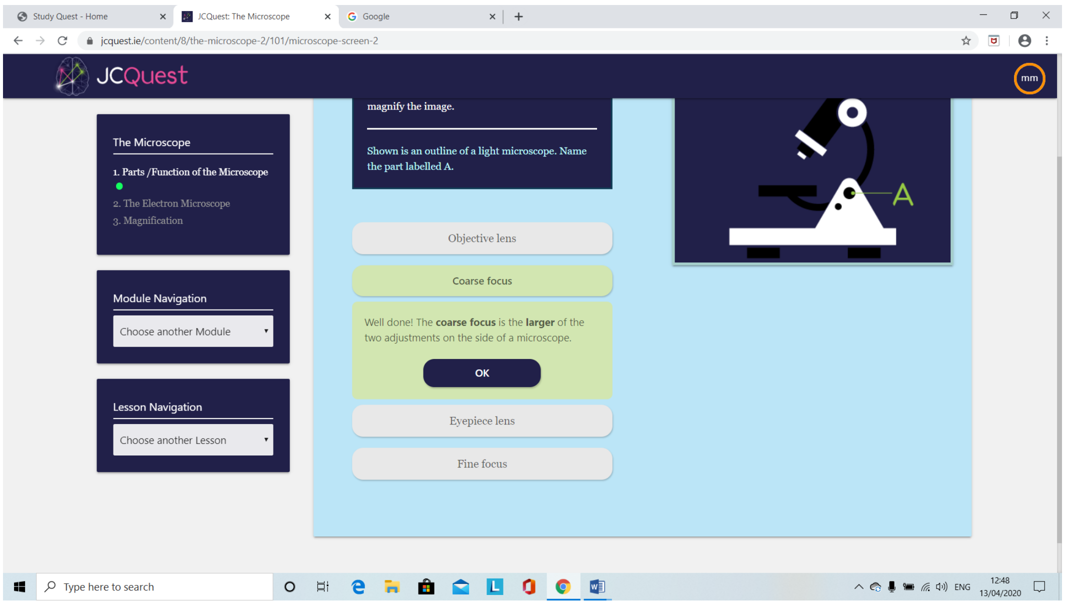

Figure 16: Example of using praise for a correct answer in StudyQuest

4.2 StudyQuest in a European Context.

While the StudyQuest system is based primarily around the Irish Junior Science curriculum, there are many overlaps where it can be modified and adapted to other European countries.

For instance, in Denmark students learn about the structure and function of the human body; blood circulation and respiration in human beings and other animals (TIMSS, 2015). StudyQuest provides a module on "How Our Body Systems Interact" that corresponds closely to the Danish Learning outcomes in this topic area.

Similarly, in Poland, where the Polish curriculum at the lower Secondary level science is divided into four subjects: Geography, Biology, Chemistry, and Physics. The curriculum describes the teaching objectives for each subject. Biology, for example, includes the structure and functions of plants, which can be found under the module 'Photosynthesis' in StudyQuest.

In Turkey, from grades 4 to 8 the Science curriculum includes the structure and features of matter. A similar approach can be found in Force and Work in StudyQuest

Included in the general objectives of the Greek Science curriculum is to encourage the ability of applying scientific knowledge in everyday life (Kollas, 2007). An example from StudyQuest includes under the module on Electricity. See below.

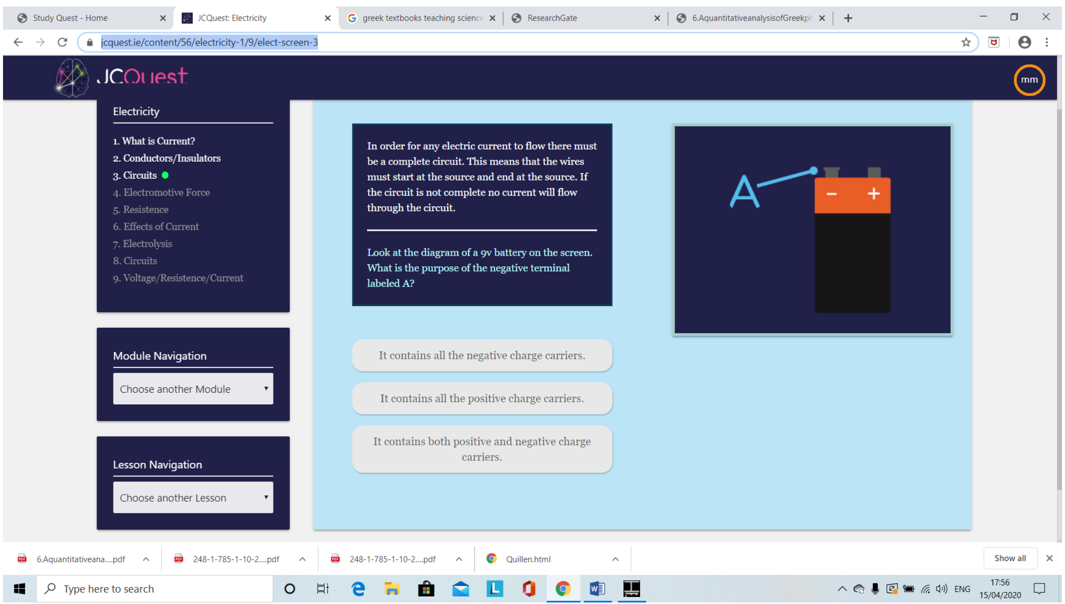

Figure 17: An example from StudyQuest on how principles learned can be applied ot real-world contexts

4.3 Data Analytics in StudyQuest

Using StudyQuest, a teacher can set up their school and create classes to monitor student progress and homework assignments on an ongoing basis. Thus, it allows the student to work independently and at their own pace (Mahon, 2012). Data analytics are provided that allows a teacher to view their students' active use of the system and as a result inform their strategies based on their student's individual learning needs. Teachers can also use the relevant data to share with other colleagues or parents to develop a shared vision of how to support the learning opportunities for students.

5 REFERENCES

Alacaci, C., & Erbas, A. K. (2010). Unpacking the inequality among Turkish schools: Findings from PISA 2009. *International Journal of Educational Development*, 302 (2), 182-192.

Anderson, L.W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing; A review of Bloom's taxonomy of educational objectives*. New York, NY: Longman.

Ayas, A. (2012). An Examination of Turkish Science Curricula from a Historical Perspective with an Emphasis on Learning Outcomes, in S. Bernholt & P. Knut Neumann (eds) *Making it Tangible. Learning Outcomes in Science Education*, New York: Waxmann.

Baartman, L.K.J., Bastiaens, T.J., Kirschner, P.A., & Van der Vleuten, C.P. M. (2006). The wheel of competency assessment: Presenting quality criteria for competency assessment programs*. Studies in Educational Evaluation*, 32, 153-170.

Baleni Z. "Online formative assessment in higher education: Its pros and cons" (2015).*The Electronic Journal of e-Learning* , 13 (4), 228-236.

Bangert-Drowns, R.L., Kulik, C.C. Kulik, J.A., & Morgan, M.T. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research*. 61 (2),213-238.

Bloom, B.S., Krathwohl, D.R., and Masia, B. B. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals*. New York: D. McKay.

Briggs, D.C., Alonzo, A.C. Schwab, C., & Wilson, M. (2006). Diagnostic assessment with ordered multiple-choice items. *Educational Assessment*, 11, 33-63.

Caldwell, J. (2007). Clickers in the large classroom: Current research and best-practice tips. *CBE Life Sciences Education*. 6 (1), 9-20.

Charman, D. (2000). Issues and impacts of using computer-based assessments (CBAs) for formative assessments, in S. Brown, P. Race & J. Bull (eds) *Computer-assisted Assessment of students*, London: Kogan Page.

Chien, Y., Chang, Y., & Chang, C. (2016). Do we click in the right way? A meta-analytic review of clicker-integrated instruction. *Educational Research Review*, 17, 1–18.

Danish Technological Institute (2015). *Does the EU need more STEM graduates*? European Commission. Brussels.

DES (2015a). *Digital Learning Framework for Secondary Schools* (2015-2020). Dublin.

DES (2015b). *Framework for Junior Cycle*. Department of Education and Skills. Dublin.

Douglas, M., Wilson, J., & Ennis, S. (2012). Multiple-choice question tests: A convenient, flexible, and effective learning tool? A case study. *Innovations in Education and Teaching International*, 49, 111-121.

Duss, K. (2018). *Formative Assessment and Feedback Tool*. Basle: Springer Gabler.

Elmahdi, I., Al-Hattami, A., & Fawzi, H. (2018) Using Technology for Formative Assessment to Improve Students' Learning. *The Turkish Online Journal of Educational Technology*. (17), 2, 182-188.

Eurydice (2018) The information Network on Education in Europe. Accessed at https://eacea.ec.europa.eu/national-policies/eurydice/content/poland_en

European Parliament - Committee on Employment and Social Affairs (2013). *How can the European Union contribute to creating a hospitable environment for enterprises, businesses and start-ups to create jobs?* European Parliament.

Galitz, W. (2007). *The Essential Guide to User Interface Design: An Introduction to GUI Design Principles and Techniques*. New York: John Wiley & Sons.

Gilakjani, A.P., Leong, L.M. & Ismail, H.N. (2013). Teachers' Use of Technology and Constructivism. *I.J.Modern Education and Computer Science*. 4, 49-63.

Gronlund, N. (2004). *Writing Instructional Objectives for Teaching and Assessment*. London: Prentice Hall.

Hattie, J. (2009). The Black Box of Tertiary Assessment: An Impending Revolution. In L. H. Meyer, S. Davidson, H. Anderson, R. Fletcher, P.M. Johnston, & M. Rees (Eds.), *Tertiary Assessment & Higher Education Student Outcomes: Policy, Practice & Research* (pp.259-275). Wellington, New Zealand: Ako Aotearoa

Hattie. J. & Timberley, H. (2007). The power of feedback. *Review of Educational Research*. 77 (1), 81-112.

Haudek, K.C., Kaplan, J.J., Knight, J., Long, T., Merrill, J., Munn, A., Smith, M., & Urban-Lurain, M. (2007). Harnessing Technology to Improve Formative Assessment of Student Conceptions in STEM: Forging a National Network. CBE Life Sciences. 10 (2), 149-155.

Hellenic Republic. Ministry of Finance (2018). *Greece: A Growth Strategy for the Future.* Accessed at https://euagenda.eu/upload/publications/untitled-181813-ea.pdf

Hopfenbeck, T., Florez Petour, M.T., & Tolo, A. (2015). Balancing tensions in educational policy reforms: large-scale implementation of Assessment for Learning in Norway, *Assessment in Education: Principles, Policy & Practice*, 22, 1, 44-60.

Johnson, D. (2015). *Teaching Outside the Lines: Developing creativity in every learner*. London: Sage Publications.

Kosma, R. (2008). *Transforming Education: Assessing and Teaching 21st Century skills*. The European Commission for Joint Research Centre.

Lane, R., Parrila, R., Bower, M., Bull, R., Cavanagh, M., Forbes, & A.,Skrebneva, I. (2019*). Literature review: formative assessment evidence and practice.* Melbourne: Australian Institute for Teaching and School Leadership (AITSL).

Lasry, N. (2008). Clickers or Flashcards: Is there really a difference? *The Physics Teacher.* 46(4), 242-244.

Little, J.L. (2018) The role of multiple-choice tests in increasing access to difficult-to-retrieve information, *Journal of Cognitive Psychology,* 30, 5-6, 520-531.

Mahon, K. L. (2012). Using Pupil Response Systems to Improve Pupil Outcomes. DYMO Mimio Interactive Teaching Technologies.

Maier, U., Wolf, N., & Randler, C. (2016). Effects of a computer-assisted formative assessment intervention based on multiple-tier diagnostic items and different feedback types. *Computers & Education*, 95, 85–98.

Marsh, E. J., Roediger, J.L.III, Bjork, R.A., & Bjork, E.L. (2007). The memorial consequences of multiple-choice testing*. Psychonomic Bulletin & Review*, 14, 194-199.

Mathelitsch, L. (2013). Competencies in Science Teaching. *Center for Educational Policy Studies*. (3), 3. 49-64.

McClintock, R. (1992*). Power and pedagogy: Transforming education through information technology*. New York: Teachers College Press.

NCCA (2015). *Key Skills of Junior Cycle*. Dublin: The Stationery Office.

Nicol, D. (2010). From monologue to dialogue: improving written feedback processes in mass higher education. Assessment & Evaluation in Higher Education. 35 (5),501-517.

Nguyen, Q., Thorne, S. & Rienties, B. (2018). How do students engage with computer-based assessments: impact of study breaks on intertemporal engagement and pass rates. *Behaviormetrika* 45, 597–614.

OECD (2009) PISA. *Assessment Framework: Key Competencies in Reading, Mathematics and Science*. OECD. Paris.

OECD. (2009). *Review on Evaluation and Assessment Frameworks for Improving School Outcomes*. OECD. Paris.

OECD (2013), PISA 2012 *Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science* (Volume I, Revised edition), OECD Publishing. http://dx.doi.org/10.1787/9789264201118-en

OECD (2013), "*Trends in evaluation and assessment", in Synergies for Better Learning: An International Perspective on Evaluation and Assessment*, OECD Publishing, Paris.

OECD (2018). Results from Pisa 2018. Accessed at https://www.oecd.org/pisa/publications/pisa-2018-results.htm

Ozuru, Y., Briner, S., Kurby, C.A., & McNamara, D.S. (2013). Comparing comprehension measured by multiple-choice and open-ended questions. *Canadian Journal of Experimental Psychology*, 67, 215-227.

Pellegrino, J.W. (2013). Proficiency in Science: Assessment Challenges and Opportunities. *Science,* 349 (6130), 320-323.

Quillin, K., & Thomas. S. (2015). Drawing-to-Learn: A Framework for Using Drawings to Promote Model-Based Reasoning in Biology. *CBE Life Sciences Education.* 14 (1),

Rohrer, D., & Pashler, H. (2012). Learning styles: Where's the evidence? *Medical Education*, 46, 34-35.

Russell, M.K. (2010). Technology-aided formative assessment of learning: new developments and applications. In H.L. Andrade, & G.J. Cizek (Eds.) *Handbook of Formative Assessment* (pp.125-138). New London: Routledge.

Scalise, K., & Gifford, B. (2006). Computer-based assessment in e-learning: a framework for constructing "immediate constraint" questions and tasks for technology platforms. *Journal of Technology, Learning and Assessment.* 4 (6), 44.

Serova, H., Sternadel, D., & Mašidlauskaitė, R. (2017). '*Assessment practices for 21st century learning: review of evidence*', NESET II report, Luxembourg: Publications Office of the European Union.

Sheard, M.K., & Chambers. B. (2014). A case of technology-enhanced formative assessment and achievement in primary grammar: How is quality assurance of formative assessment assured? *Studies in Educational Evaluation*.43,14-23.

Shute, V.J. (2008). Focus on Formative Feedback. *Review of Educational Research*. 78,153-189.

Shute, V.J. (2009). Simply Assessment. *International Journal of Learning and Media*, 1 (2), 1-11.

Singh, S. & Yaduvanshi, S. (2015). Constructivism in Science Classroom: Why and How. *International Journal of Science and Research Publications,* 5, (3). 1-5.

Taser, M. F. (2013). How do Science Teachers View and Teach the Nature of Science? A Classroom Investigation. *Education & Science*. 38, (167), 65-80.

Turiman, P., Omar, J., Mohd Daud., & Osman, K. (2012). Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills. *Social and Behavioral Sciences.* 59, 10-116.

Turkmen, L. & Bonnstetter, R.J. (2007). Influences of some philosophical approaches in the historical development of Turkish science education. *Science Education International*. 2007;18(1):139–151.

UNESCO-IBE (2011) *World Data on Education: Seventh edition 2010-11*. Geneva. UNESCO.

Volant, L. (2018). *Effective Pedagogies for a Redeveloped Primary Curriculum*. NCCA. Dublin.

Yin, Y., Olson, J., Olson, M., Solvin, H., & Brandon, P.R. (2015) Comparing Two Versions of Professional Development for Teachers Using Formative Assessment in Networked Mathematics Classrooms*, Journal of Research on Technology in Education*, 47, 1, 41-70.

YU, Z. (2017). Identifying Student Satisfaction in the Flipped English Class enhanced with Clickers. *International Journal of Information and Communication Technology Education*. 15, (4), 25-49.

Zhu, C., Urhahne, D. (2018. The use of learner response systems in the classroom enhances teachers' judgement accuracy. *Learning and Instruction*. 58, 255-262.