SOWISO

Part 1 of a four-part series

Complex problems and solutions in maths education

Leveraging technology for efficiency and time management

Version: November 19, 2019

Table of Content

1. Introduction

The study of mathematics is foundational for plenty of other subjects. Engineering, Biology, Nursing, Business and Chemistry are all subjects which require a fundamental understanding of mathematics when studied at degree level[1,2,3,4]. Many universities require their non-mathematics students to pass a foundational mathematics course before they can continue with their proper degree. These foundational maths courses can pose significant problems for teachers and students.

Foundational mathematics programmes are often large and include students from different disciplines. Students have varied levels of prior maths knowledge, differing levels of motivation and interest and frequently, different levels of spoken language. International students may have followed very different mathematics curricula to the local one. Bamforth et al. note, 'students without the assumed mathematics knowledge and skill may be at risk of failing or underachieving'[5]. Sadly a failing grade in a foundational mathematics course can result in interrupted main study, repeated classes and ultimately failing a degree.

Teachers commonly struggle with large classes and a resulting lack of time and focus; apathy from students and high failure rates for an important course.

––

[1] *Broadbridge. P. & Henderson, S. (2008) 'Mathematics Education for 21st Century Engineering Students: Final Report', Australian Mathematical Sciences Institute & Carrick Institute. Strawberry Hills, NSW: Carrick Institute;*

[2] *Bialek, W. & Botstein, D. (2004) 'Introductory science and mathematics education for 21st-century biologists', Science, 303(5659): 788-790.*

[3] *Croft, A.C., Harrison, M.C. & Robinson, C.L. (2009) 'Recruitment and retention of students - an integrated and holistic vision of mathematics support', International Journal of Mathematical Education in Science and Technology, 40(1): 109-125.*

[4] *Loughlin, Wendy A., Watters, Dianne J., Brown, Christopher L. & Johnston, Peter R. (2015) 'Snapshot of mathematical background demographics of a broad cohort or first year chemistry science students', International Journal of Innovation in Science and Mathematics Education 23(1): 21-36.*

[5] *Bamforth, S., Robinson, C.L., Croft, T. & Crawford, A. (2007) 'Retention and progression of engineering students with diverse mathematical backgrounds', Teaching Mathematics and its applications, 26(4): 156-166.*

These unique problems have led to broader fears about both the quality of mathematics education at universities and HE institutions and the abilities of students to study mathematics. This caused the London Mathematical Society to cite 'unprecedented concern' over the mathematical preparedness of undergraduates[6]. While this is an issue common to maths-based degrees as well as degree courses including a foundational maths course, the so-called 'Maths Problem' is gaining notoriety.

Various solutions have been offered for this well documented problem including intensive summer schools or crash courses, online instructional materials, on-site support centres, computer aided assessments and problem based learning strategies[7,8,9,10]. These solutions have had differing degrees of success across various institutions, and are often successful only with certain students or within certain time frames. SOWISO, on the other hand, has taken a different approach.

––

[6] *London Mathematical Society (1995) Tackling the mathematics problem. London: London Mathematical Society. Available at: http://mei.org.uk/files/pdf/Tackling_the_Mathematics_Problem.pdf*

[7] *Bamforth et al (2007)*

[8] *Llorens, M., Nevin, E. & Mageen, E. et al. (2014) 'Online resource platform for mathematics education', in Proceedings 44th Annual Frontiers in Education (FIE) Conference (22-25 October) Madrid: 1865-1872.*

[9] *Broadbridge & Henderson (2008)*

[10] *M. Cazzola, M. (2008), "Problem-Based Learning and Mathematics: Possible Synergical Actions", in L. Gomez Chova, D. M. Belenguer, and I. Candel Torres (eds.), ICERI2008 Proceeding, IATED (International Association of Technology, Education and Development), Valencia, Spain, 2008.*

2. The digital solution

SOWISO has spent a long time considering and researching the issue of mathematics learning for non-maths students and the unique issues it involves. Any solution to the maths problem needs to be efficient, effective and relatively low-cost, in order to be widely adopted by the HE institutions who need it. SOWISO has combined two of the most effective strategies to challenge this issue - those of digital learning[13] and problem based learning[14, 15] approach.

This has resulted in the SOWISO online personalized learning platform, which is specifically designed to assist students and teachers operating in maths-related subjects.

Digital learning platforms are becoming increasingly popular solutions across all educational sectors. Although online learning platforms are in no way a substitute for properly trained and funded teaching staff, they can provide significant assistance for both students and teachers. The scope of such tools is vast, as is the variety of educational tools and their uses.

Digital tools are proven to be particularly effective when part of a blended learning approach.[16, 17] This approach combines face-to-face teaching with computer technologies, allowing both digital technologies and teaching staff to 'fill in the gaps' left by the other. The combination, if implemented correctly, can:

- Allow teaching staff more contact time with students
- Provide options for students with different working and learning patterns
- Lower institutional costs

——

[13] Llobregat-Gomez et al. (2015) cite a study which yielded an attendance rate of 95% with a 90% success rate for students, a number previously unheard of in the course.

[14] *Şendağ, S. & Odabaşı, H. F., 'Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills', Computers & Education 53(1): 132-142.*

[15] *Lazakidou, Georgia & Retalis, Symeon (2010) 'Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics', Computers & Education 54: 3-13.*

[16] *Llobregat-Gomez et al (2015)*

[17] Ndloui, Mdutshekelwa C. & Mostert, I. (2018) 'Teacher Perceptions of Moodle and Throughput in a Blended Learning Programme for In-Service Secondary School Mathematics Teachers', Africa Education Review, 15(2): 131-151.

A particularly popular form of blended learning is colloquially known as 'Flipping the Classroom[18]', wherein students complete the majority of their learning work at home, usually with the assistance of a digital learning platform. Teacher-facing time is then used for problem solving, questions and student-teacher discussions.

However, many teachers and administrators shy away from such online platforms and digital tools because of fears about the complexity of the tool or worries about the difficulties of integration[19] into already existing technologies. Often teachers feel under-confident about new technology and prefer to rely on traditional pedagogies and teaching tools.

Many studies have demonstrated that if online platforms are integrated effectively, and teachers are confident with using new tools, then they create significant benefits for students, teachers and administrative staff in higher education.

Various online platforms are used across Higher Education, with differing results and for different purposes. The SOWISO platform is based on giving mathematics students repeated chances to learn and practice the material, improving their retention and understanding with each use.

SOWISO uses repetitive formative and diagnostic assessment to allow students repeated opportunities to learn and practice mathematical concepts.[20] Teachers are provided in-depth and accurate overviews of their students' results, allowing them to determine early on which students are struggling or which concepts are difficult for many to grasp. SOWISO improves teaching and learning from both ends of the spectrum, improving the experience for all.

––

[18] Educational Horizons (2011) 'Flipping the classroom', Educational Horizons 90(1): 5-7.

[19] Garrison, D. R. & T. Anderson (2003) E-learning in the 21st Century: A framework for research and practice. London: Routledge/Falmer.

[20] Heck, A. (2017) 'Using SOWISO to realize interactive mathematical documents for learning, practising, and assessing mathematics', MSOR Connections 15(2).

Benefits of the SOWISO platform include:

- Full control over learning material for teachers, including the ability to edit or reorder pre-existing material or create learning materials from scratch
- Randomized and open questions
- Adaptive learning functionality, which chooses the difficulty level of the next question based on previous answers
- Ability of students to access learning materials at any time
- Advanced learning analytics for teachers, based on a variety of criteria
- Immediate and intelligent feedback for maths problems completed
- Formative and non-formative assessments
- Various degrees of integration with Learning Management Systems, including Canvas, Blackboard and Moodle

SOWISO technology has been subject to rigorous academic assessment and several studies on its successes have been written.[21] Part of creating a useful tool involves delving deeply into the nature of the problems faced by teachers and students, both before and during use of the SOWISO tool. This following section will highlight this more clearly, before moving onto a detailed analysis of one specific problem from the perspective of teaching staff.

––

[21] See Heck, A. & Brouwer, N. (2015) "Digital assessment-driven examples-based mathematics for computer science students", in N.Amado & Carreira (eds.) Proceedings of the 12th International Conference on Technology in Mathematics Teaching. University of Algarve, Portugal, pp.403-411.

3. Purpose of this paper

As previously discussed, the issue of mathematics teaching to non-maths students in Higher Education can be complicated. In order to understand the issue to its fullest extent, it is essential to break down the complexities of the issue into various subproblems and consider them critically. This paper, as well as the series it belongs to, seeks to consider in depth the various subproblems that exist within the issue of teaching mathematics to non-maths students at university.

By analysing these subproblems in greater depth, it improves the possibility of deciding upon and implementing solutions. Only by providing solutions to these sub-problems can the overarching issue of maths in higher education be tackled. From our own perspective, analyzing problems in depth allows us to pre-empt any problems and integrate solutions into our digital platform.

In addition to breaking down the various subproblems of the field, these papers will consider mathematics teaching from two angles - from the student perspective and from the teacher perspective. It is essential that any solution includes the viewpoints of both parties. A problem suffered by students has the ability to derail the teaching practices of higher education staff and vice versa. Only an approach which truly integrates the issues and complaints of both groups has hope of succeeding.

This whitepaper will focus on a set of subproblems from the perspective of teaching staff, and then demonstrate several solutions which are used by SOWISO to combat these issues. It is hoped that this series of whitepapers can be helpful for both teachers and higher education administrators to ensure that digital online platforms such as SOWISO are a benefit, not a hindrance to teaching staff.

4. Common teaching problems and how to solve them

Teaching problem: Lack of time

Key problem: Time management is a significant issue for teaching staff of almost all subjects in Higher Education.[22]

It has been noted that 'rules are changing, and there is increased pressure on institutions of higher education to evolve, adapt or desist'[23]. This pressure is often passed on to teaching staff. Teachers and professors must balance teaching with research alongside social/emotional support duties and often an additional administrative role.

Teachers regularly do not have enough time to prepare lessons and complete teaching tasks. Such tasks include grading papers or marking homework, finding or creating teaching materials, finding or creating grading/homework materials and allowing time for monitoring and supporting students, particularly those who are struggling or need to catch up. This is particularly prevalent in courses with a diverse body of students or many students of different nationalities.

In addition to this, teachers rarely have time to dedicate to learning innovation, or to consider new approaches to course material. Creating a new learning course from scratch is complicated and time consuming. Teaching staff are sometimes not compensated for this extra work, regardless of the impact on teaching quality. In many institutions teachers are evaluated on research-based criteria rather than teaching-based criteria, leaving little motivation for innovative approaches.

––

[22] *Berg, Maggie & Seeber, Barbara K. (2016) The Slow Professor: Challenging the culture of speed in the Academy. Toronto: University of Toronto Press.*

[23] *Swail, W.S. (2002). 'Higher education and the new demographics: Questions for policy.' Change Magazine, 34(4), 15-23. pp.16*

Several solutions are available to assist with this issue. Although the issue of limited time for teaching staff will never be entirely removed, it can be modified through the use of various digital technologies, including the SOWISO platform which is specifically designed for a mathematics teaching environment.

Solution 1: Automate repetitive tasks

Online learning tools can improve efficiency and lighten the workload for teachers across disciplines. When properly implemented, such platforms can take over some of the repetitive tasks such as checking and grading homework. This method of task management not only removes some of the time burden from teaching staff but also provides an in-depth overview of which students are struggling with certain tasks. While this overview can be achieved through manually grading work, it is easier to track and analyze using software.

The SOWISO platform uses open questions, rather than multiple choice.[24] Students can enter whatever they choose into the answer space provided to try to solve the maths problem provided. Sometimes students will enter the correct answer immediately, others will make a wild guess. The majority of students will make an attempt but will need some coaching to find the correct answer. This guidance would traditionally be undertaken by a teacher, but the SOWISO platform can perform that function on its own.

SOWISO uses targeted feedback to help students progress in problem-solving. This comes in the form of lines of text which pop up depending on the input of the student. When the answer is incorrect, the SOWISO platform will point out where and allow students additional attempts. This method uses the theory of Guided Discovery in which students develop their own understanding from a set of materials or from within a teaching environment. This 'allows them to be active participants in their own learning'.[25]

Using SOWISO students can "discover" the correct approach through trial-and-error, while targeted feedback makes the process more efficient and ensures that students feel supported. Discovery and guidance are combined to ensure students understand the teaching materials as well as engaging with them.

––

[24] *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/Revue canadienne de psychologie expérimentale, 67(3), 215-227.*

[25] *Fen Ng, Chiew & Kiat Ng, Poh (2013) 'Teaching strategies and their impacts on the English proficiency of young Malaysian learners'. Frontiers of Language and Teaching, 4: 186-195. Pp.187.*

Solution 2: Limitless and randomized practice materials

Creating teaching and practice materials is a time-consuming process which often becomes tiresome for teaching staff. Sometimes teachers avoid this time-drain by reusing old materials. However digital platforms provide a source of limitless and randomized practice materials, made available to both teaching staff for lessons, and students for practice. The randomization process is automatic, and varies practice problems both by exercise and variable.

This provides an extensive source of material for teachers, who could never hope to cycle through all of the endless variations. Using SOWISO, teaching staff can use pre-made plug-and-play courseware through digital platforms, rather than creating their own customized courses. This plug-and-play courseware is based on standard mathematics criteria, arranged in a logical progression, much like a textbook. This process saves time in course and material creation but does not compromise on quality or quantity.

Alternately teachers can also adapt the plug-and-play material by editing material or adding their own. This is particularly helpful with students in a course where mathematics is not the primary focus. Teachers may want to include material that links together maths and the main teaching subject, such as biology or engineering. While this approach takes more time, it allows teachers more control over the content they teach and the other in which they teach it. Furthermore this time investment is repaid each time that the content is reused, which could be every year of teaching. Of course, some teachers prefer to completely build their courses from scratch, which is a feature also supported on the SOWISO platform.

As SOWISO takes over many time-consuming tasks, teachers have move time to be able to focus on other teaching tasks, such as individual guidance of students, more targeted teaching or interesting case studies. All these things benefit the learning experience and improve students' chances for success. These tasks cannot easily be performed by algorithms but by outsourcing some tasks to a digital learning platform, teachers can spend time on these activities which are frequently missed out on due to time constraints.

Teaching problem: Diverse student body

Key problem: A sub-problem which contributes to a lack of time for teachers is an internationally diverse student body.

Often students in maths-related subjects come from a diversity of academic backgrounds, with differences in maths knowledge and ability. This can create an issue for teaching staff who need to get some students 'up to speed', while ensuring other students are challenged by the work and supported in their efforts. Frequently students will be from a different country of origin, resulting in a language barrier which can further hamper teaching efforts. National curricula for mathematics can differ significantly, creating more issues in getting students to the same starting point in learning maths at higher education level.

Solution: Emphasis on online distance education

By combining digital learning platforms with traditional pedagogic methods, the potential for teaching interactions is increased. Face-to-face learning can be combined with distance learning, as is typical of a blended learning approach. In the case of maths courses for non-maths students, a possible solution to different starting knowledge points could be the use of relatively hands-off distance education. Online summer schools using the same digital technologies used in class move the responsibility for learning towards the student, promoting the ideal of self-study.

This method is double beneficial as it encourages students to continue using the digital platform and self-sufficient studying during term-time as well as during holidays. When a teacher prepares a formative or summative test at the end of the summer course or at the start of the regular first-year courses, students also have a very clear incentive to prepare themselves better for the start of the academic year.

This approach also allows and encourages students to study at their own pace, provided they meet the deadlines. Evidence has shown that allowing students to work to their own pace, in their own manner can improve outcomes[26], particularly for mathematics. Studies have shown that personalized learning, which requires 'a clear understanding of the needs and goals[27] of each individual student and the tailoring of instruction to address those needs and goals' is very effective.

Teaching problem: Implementation of digital tools

Key problem: Although digital tools have become relatively common in the last 10 years, professionals in higher education continue to be cautious with them, often due to implementation issues.

Poor implementation processes mean tools malfunction or are poorly understood by students and teachers, resulting in confusion and more time spent overcoming issues. While much research has been done into effective implementation, there is a wide variation in the ease of use for different tools. This is a problem which exists across the EdTech space.

Solution: Solid onboarding and implementation practices

It should be the responsibility of EdTech companies to ensure their tool is usable and efficient, particularly in the initial stages. There are several things that EdTech companies can do to assist institutions and teachers in using digital tools, including:

- Take UI/UX design into serious consideration when designing a tool or platform. Good design means teachers and students can instinctively use tools in the most efficient way for their learning style and course type;
- Preparing helpful documentation to make sure any questions teachers may have can be quickly answered. Replies within 24 hours are unhelpful in the face of a tool malfunctioning 5 minutes before the start of a class;
- Ensuring there is an in-person onboarding process trained in teaching staff how to use a tool effectively and efficiently;
- Providing excellent support channels for more in-depth questions or problems.

——

[26] Hodson, Hal (2014) "Personalised learning lets children study at their own pace", The New Scientist [online] (30-12-2014). Available at https://www.newscientist.com/article/mg22530024-200-personalised-learning-lets-children-study-at-their-own-pace/

[27] Pane, John F., Steiner, Elizabeth D., Baird, Matthew D., Hamilton, Laura S., & Pane, Joseph D., Informing Progress: Insights on personalized learning implementation and effects. Santa Monica, CA: RAND Corporation, pp.2

When these stages are observed, implementation is generally successful, improving the trust of teachers and students and allowing everyone to get the best out of digital technologies. If implementation can be done quickly and easily this is a significant asset for teachers and administrators.

As previously noted, innovation can be the most difficult at the outset, while creating and implementing a new approach or new materials. Teaching staff rarely have time to juggle research and teaching requirements with innovative content creation, and such innovation takes time and effort. Digital learning platforms can remove much of the hassle of creating new content and the struggle of ensuring it is integrated into the current university system. SOWISO provides teachers the opportunity to use pre-existing content, alter and edit it or create entirely new content, all within a system which is easily integrated into an institution's LMS.

5. Conclusion

It is clear from this paper that the problems that teaching staff face in teaching mathematics to non-maths students are deep-rooted and complex. Furthermore many of these problems are not limited to mathematics courses, but span across disciplines.

Nevertheless SOWISO believes that through well-designed digital platforms, using problem-based learning and content specifically designed for the subject at hand, high quality maths learning is possible for all students. Equally importantly, effective and efficient digital tools exist to assist teachers who teach this subject.

Teaching staff at Higher Education institutions are increasingly pressed for time, with the demands of research, teaching and administrative tasks. Online learning platforms can help to automate many tasks, but the most helpful platforms are those which are targeted to the specific situation. As is clear from this and previous whitepapers, the problems facing teachers of maths to non-maths students differ from other disciplines. Large and diverse teaching groups, student apathy and the high stakes nature of the course combine with time and activity pressures on teaching staff.

SOWISO has thought carefully about the struggles facing teachers and designed a learning tool to address those. By using randomized testing and allowing students various ways to approach learning materials, we hope to improve student outcomes and relieve some of the burden on teachers at the same time.

Effective implementation and good design are key to our approach, as is our continued desire to listen to the opinions and feedback of students and teachers alike. If you have any feedback or comments about the SOWISO tool or mission, we would love to hear from you. You can get in touch with us through our website or by sending an email to info@sowiso.com.

If you would like to learn more about any aspect of SOWISO and our work, or read some of our other research papers, please visit www.sowiso.com for plenty more information.

6. About SOWISO

SOWISO is an interactive and personalized mathematics learning platform, designed for students uncomfortable with the subject. The platform guides students along an individual learning path, giving hints, identifying weaknesses and explaining complex concepts. SOWISO can be used by individuals or institutions as a support system for large classes of diverse learners.

SOWISO uses a variety of techniques to leverage mathematics teaching for a broad range of students. Several features make learning attractive and enjoyable for students and flexible and easy to integrate for teachers.

Personalized learning

The SOWISO platform analyses student work and highlights mistakes and weaknesses. The platform provides hints specific to a student's learning journey, meaning individual students get individual attention no matter how large a class is.

Adaptivity

Students can find their own path through maths content thanks to adaptive algorithms. The SOWISO platform constantly analyzes student comprehension and provides appropriate exercises. Testing provides insights into which topics have been mastered and which need more attention.

Learning Analytics

SOWISO provides extensive analytic data for every course. Teachers can gain valuable insights into how well students are learning, as well as diving deeper into subchapters, topics or even individual exercise attempts. Teachers can get information about individual students or the student body at large, allowing teachers to identify issues with content or individuals having trouble.

Automated testing

The SOWISO platform is capable of implementing randomized tests for students, checking and grading answers so that teachers do not have to undertake extra work. Numerous testing types are supported including diagnostic, formative or summative testing. Teachers can change the window of availability, number of attempts or a minimum passing grade among other adaptations.

Gamification

Teachers can activite gamification elements on the SOWISO platform, allowing students to gain achievement badges for important and informal tasks. Gamification further engages students and improves learning outcomes overall.

Integration

SOWISO can be fully integrated into an LMS like Moodle or Canvas or can be used in a cloud-based form using access codes and hyperlinks. Full integration allows for grades to be pushed back into an LMS gradebook, reducing administrative work for teachers

If your are interested in working with SOWISO, please contact us at:

info@sowiso.nl

Exercise

Students get detailed hints and feedback on every answer attempt

Feedback

Calculate the derivative $h'(x)$ of $h(x) = 7 \cdot \sin(8 \cdot x)$.

$h'(x) = 7 \cdot \cos(8 \cdot x)$	✗	No, you may have forgotten to multiply by $g'(x)$, in which $g(x) = 8 \cdot x$.
$h'(x) = 7 \cdot \cos(56 \cdot x)$	✗	The chain rule indicates that the derivative contains $f'(g(x))$, in which $f(x) = 7 \cdot \sin(x)$ and $g(x) = 8 \cdot x$. Thus, the the argument of the cosine must be equal to $g(x)$. This is not the case in your answer.
$h'(x) = 56 \cdot \cos(8 \cdot x)$	✓	Great job

Theory

We provide explanations with interactive elements

Trigonometry: Angles with sine, cosine and tangent

Angles in radians

So far we have expressed angles in degrees, but in mathematics angles are often expressed in radians. To introduce radians we will use a circle with radius 1. We call this the unit circle.

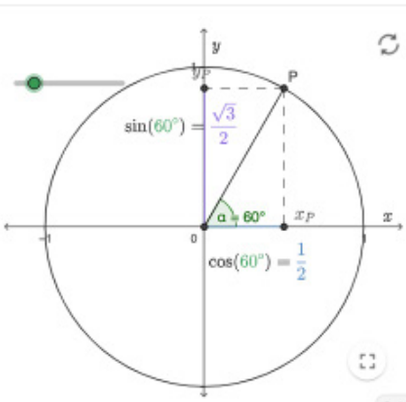
Unit circle

The **unit circle** is a circle with origin center $[0, 0]$ and radius 1.

The point $P = [x_P, y_P]$ starts at $[1, 0]$ and moves counterclockwise across the unit circle. The **angle of rotation** is called α.

Therefore $\sin(\alpha) = y_P$ and $\cos(\alpha) = x_P$.

In this way we can also define angles greater than $90°$ degrees with the sine and the cosine.



7. Bibliography

Bamforth, S., Robinson, C.L., Croft, T. & Crawford, A. (2007) 'Retention and progression of engineering students with diverse mathematical backgrounds', Teaching Mathematics and its applications, 26(4): 156-166.

Berg, Maggie & Seeber, Barbara K. (2016) The Slow Professor: Challenging the culture of speed in the Academy. Toronto: University of Toronto Press.

Bialek, W. & Botstein, D. (2004) 'Introductory science and mathematics education for 21st-century biologists', Science, 303(5659): 788-790.

Broadbridge. P. & Henderson, S. (2008) 'Mathematics Education for 21st Century Engineering Students: Final Report', Australian Mathematical Sciences Institute & Carrick Institute. Strawberry Hills, NSW: Carrick Institute.

Cazzola, M. (2008), "Problem-Based Learning and Mathematics: Possible Synergical Actions", in L. Gomez Chova, D. M. Belenguer, and I. Candel Torres (eds.), ICERI2008 Proceeding, IATED (International Association of Technology, Education and Development), Valencia, Spain, 2008.

Croft, A.C., Harrison, M.C. & Robinson, C.L. (2009) 'Recruitment and retention of students - an integrated and holistic vision of mathematics support', International Journal of Mathematical Education in Science and Technology, 40(1): 109-125.

Educational Horizons (2011) 'Flipping the classroom', Educational Horizons 90(1): 5-7.

Fen Ng, Chiew & Kiat Ng, Poh (2013) 'Teaching strategies and their impacts on the English proficiency of young Malaysian learners'. Frontiers of Language and Teaching, 4: 186-195. Pp.187.

Garrison, D. R. & T. Anderson (2003) E-learning in the 21st Century: A framework for research and practice. London: Routledge/Falmer.

Heck, A. (2017) 'Using SOWISO to realize interactive mathematical documents for learning, practising, and assessing mathematics', MSOR Connections 15(2).

Heck, A. & Brouwer, N. (2015) "Digital assessment-driven examples-based mathematics for computer science students", in N.Amado & Carreira (eds.) Proceedings of the 12th International Conference on Technology in Mathematics Teaching. University of Algarve, Portugal, pp.403-411.

Hodson, Hal (2014) "Personalised learning lets children study at their own pace", The New Scientist [online] (30-12-2014). Available at https://www.newscientist.com/article/mg22530024-200-personalised-learning-lets-children-study-at-their-own-pace/

Lazakidou, Georgia & Retalis, Symeon (2010) 'Using computer supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills in mathematics', Computers & Education 54: 3-13.

Llobregat-Gomez, J.A., Morano, M.D., & Rosello, L.M. Sanchez Ruiz (2015) 'Blended learning at maths with aerospace engineering freshmen', in 2015 IEEE Frontiers in Educational Conference (FIE), October 2015: 1-4. pp. 2

Llorens, M., Nevin, E. & Mageen, E. et al. (2014) 'Online resource platform for mathematics education', in Proceedings 44th Annual Frontiers in Education (FIE) Conference (22-25 October) Madrid: 1865-1872.

London Mathematical Society (1995) Tackling the mathematics problem. London: London Mathematical Society. Available at: http://mei.org.uk/files/pdf/Tackling_the_Mathematics_Problem.pdf Accessed on 15/05/2019.

Loughlin, Wendy A., Watters, Dianne J., Brown, Christopher L. & Johnston, Peter R. (2015) 'Snapshot of mathematical background demographics of a broad cohort or first year chemistry science students', International Journal of Innovation in Science and Mathematics Education 23(1): 21-36.

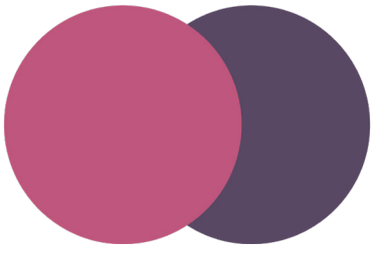
Ndlovu, M.C. & Mostert, I. (2018) 'Teacher Perceptions of Moodle and Throughput in a Blended Learning Programme for In-Service Secondary School Mathematics Teachers', Africa Education Review, 15(2): 131-151.

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/Revue canadienne de psychologie expérimentale, 67(3), 215-227.

Pane, John F., Steiner, Elizabeth D., Baird, Matthew D., Hamilton, Laura S., & Pane, Joseph D., Informing Progress: Insights on personalized learning implementation and effects. Santa Monica, CA: RAND Corporation, pp.2

Şendağ, S. & Odabaşı, H. F., 'Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills', Computers & Education 53(1): 132-142.

Swail, W.S. (2002). 'Higher education and the new demographics: Questions for policy.' Change Magazine, 34(4), 15-23.



info@sowiso.com | www.sowiso.com