

Motivation towards Mathematics Learning in the Technology-enhanced Environment

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Abstract: This paper reviews the motivation construct in mathematics learning, particularly in the technology-enhanced learning (TEL) environment. The discussion here is not limited to a single motivational theory but encompasses multiple facets of the construct. While technology can be effective in motivating students in the learning process, it should not be presumed that motivation can be improved with the mere integration of technology. To enhance motivation in the TEL environment, teachers and instructional designers need to consider students' current motivational needs as they grapple with understanding mathematical concepts. There is also the challenge of ensuring that initial motivation attributed to the novelty effects of technology be sustained so that students continue to be motivated in the long run. It is important to understand the strengths and limitations of the affordance of technology to complement mathematics learning.

Keywords: Motivation, mathematics, technology-enhanced learning

1. Introduction

Motivation has a pivotal role in mathematics education (Hannula, 2006; Walter & Hart, 2009). Numerous studies have shown that mathematics performance is strongly related to students' motivation towards mathematics learning (Schiefele & Csikszentmihalyi, 1995; Kim, Park, & Cozart, 2014; OECD, 2014a; Mullis, Martin, Foy, & Arora, 2012). This is evident from the case study of the Programme for International Student Assessment (PISA), a grand-scale international assessment conducted by the Organization of Economic Co-operation and Development (OECD) to measure students' proficiency in mathematics, science and reading every three years. It was found that highly-motivated students across the OECD countries achieved better scores, equivalent to an additional half year of schooling, than students who were not as motivated (OECD, 2014b). As such, mathematics teachers play a very important role of providing a stimulating environment that will motivate students in the mathematics classroom (Schiefele & Csikszentmihalyi, 1995; Yu & Singh, 2016; Pantziara & Philippou, 2013; Tarmizi & Tarmizi, 2010).

Teachers are urged to revise their teaching strategies to facilitate and improve students' motivation towards learning mathematics (Thien & Ong, 2015; Ismail & Awang, 2012; Kim et al., 2014). This is where technology comes into the play. Technology has been utilised extensively in education to enhance teaching and learning of mathematics (Star, et al., 2014; Foshee, Elliott, & Atkinson, 2015; Erbas & Yenmez, 2011). Such a learning environment is described as technology-enhanced learning (TEL), where Information and Communication Technology (ICT) is applied (Kirkwood & Prince, 2014). Technological tools or aids can be as general as the Internet connection, computers or laptops, and LCD projectors. They can also be subject specific, examples of which are scientific or graphic calculators, dynamic geometry software, statistical analysis software, and online learning forum or platforms. These technologies can be leveraged to benefit students in mathematics learning. One means by which this is achieved is through promoting students' motivation towards mathematics. In fact, motivation or affective characteristics have frequently been taken as predictors for mathematics performance (Thien & Ong, 2015; Gilbert et al., 2014; Walter & Hart, 2009; Hannula, 2006; Holmes & Hwang, 2016). This leads then to the role of technology in enhancing these two inter-linked factors, namely mathematics performance and motivation. In other words, when technology is employed intentionally to enhance

mathematics learning, should we presume students' motivation towards mathematics will be improved as well? Here, the authors review the motivation construct in mathematics education and the role of technology in improving mathematics teaching and learning.

2. Motivation in Mathematics Education

The scope of motivation encompasses what people desire, what goals they opt to pursue and how much effort they are willing to put in to execute their action plans, i.e. motivation explains the magnitude and direction of people's behavior (Keller, 2010). However, the conceptualisation of the motivation construct in mathematics education has been inconsistent since varying dimensions of motivation have been considered by different scholars. It is crucial to recognise various aspects of the motivation construct in mathematics learning before one can revise strategies to increase motivation.

For instance, self-efficacy (Bandura, 1994) is often associated with motivation in mathematical research (Gilbert, 2016; Skaalvik, Federici, & Klassen, 2015; Holmes & Hwang, 2016; Hannula, 2006; Star et al., 2014; Pantziara & Philippou, 2013; OECD, 2014a; Yu & Singh, 2016). Introduced by Bandura (1994), self-efficacy is about how one perceives his or her ability to complete a task. In a learning context, mathematics self-efficacy is conceptualised as students' perceptions of their competency to solve or perform mathematical tasks (Skaalvik et al., 2015). Gilbert (2016) analyses students' motivational level in mathematics learning in terms of self-efficacy and interest in mathematics. Start et al. (2014) also included self-efficacy in the motivational domain when exploring the effects of technology-based activities on motivation in mathematics. As such, students who have high mathematics self-efficacy are deemed to be highly motivated to study mathematics (Skaalvik et al., 2015).

Next, utility value, which is a part of the Expectancy-value Theory (Wigfield & Eccles, 2000), has been derived as motivation in mathematics learning as well (Thien & Ong, 2015; Holmes & Hwang, 2016; Gilbert, 2016; OECD, 2014a). The utility value embedded in the theory refers to the usefulness of a task for one's daily or future life (Wigfield & Eccles, 2000). In learning mathematics, it refers to the real-life usefulness of the material that is learnt in school. In the case of PISA 2012, students' perception on the utility value of mathematics in their future career was used to conceptualise instrumental motivation (OECD, 2014a). Gilbert (2016) observes that utility and mastery-approach goals are types of motivation related to the more cognitive-engaging mathematical tasks.

Interest is sometimes equated with intrinsic motivation in mathematics studies (OECD, 2014a; Skaalvik et al., 2015). Intrinsic motivation is defined as the inclination to do things for the sake of the activity itself, which is interesting or enjoyable (Ryan & Deci, 2000). In fact, for PISA 2012, students' responses on whether they enjoyed and had interest in learning mathematics were adopted as an index for intrinsic motivation (OECD, 2014a). Skaalvik et al. (2015) used intrinsic motivation to represent interest when exploring the relationship between motivation and mathematics performance. This conceptualisation of intrinsic motivation is grounded in the Self-determination Theory (Deci, 1972) which argues that interestingness of an activity is dominant in intrinsic motivation, where interest exists between an individual's intrinsic needs (i.e. competency, autonomy, and social-acceptance) and affordance of the activity. This suggests that one is intrinsically motivated when engaging in the activity that one is interested in.

In contrast, Hannula (2006) conceptualises motivation as a potential that cannot be directly observed. The potential refers to the force that is driven by needs and goals which are also affected by emotions at the same time, and which eventually navigates one's behaviour (Hannula, 2006). Kim et al. (2014) state that motivation should be viewed as a part of emotion, and vice versa. In other words, students' emotions, attitudes and beliefs can affect the degree of perseverance in the pursuit of goals, i.e. better grades in mathematics or mastery of mathematics.

Thus far, various aspects of the motivation construct have been discussed in the context of mathematics learning. It has been related to self-efficacy, utility value in the Expectancy-value Theory or instrumental motivation, intrinsic motivation in the Self-determination Theory, as well as interest, beliefs and emotions. Therefore, the discussion of the motivation construct in

mathematics learning in this paper is not restricted to a single motivational theory but encompasses multiple facets of the construct.

3. Student Motivation and Mathematics Performance

As mentioned earlier, previous studies have established the correlational relationship between motivation and mathematics performance (Gilbert et al., 2014; Walter & Hart, 2009; Hannula, 2006). According to PISA 2012, the relationship was better established among students who performed at an outstanding level than among lower performing students (OECD, 2014a). By adopting results from PISA 2012, Thien and Ong (2015) reported that mathematics self-efficacy and anxiety had a statistically significant effect on Malaysian students' mathematics performance. Skaalvik et al. (2015) state that mathematics self-efficacy could make a difference in students' mathematics performance while Holmes and Hwang (2016) suggested that motivation was one of the factors that contributed to mathematics success when exploring the effects of project-based learning in mathematics. Walter and Hart (2009) reported that students chose to act when motivated by tasks that had a bearing to the social and personal context. This eventually fostered the students' engagement in mathematics learning. Hannula (2006) carried out a case study to observe students' motivational behavior in relation to mathematics performance. The study concluded that students' needs and goals directed their motivational behavior, which eventually affected their mathematics learning. Students who focused on impressing their teacher (i.e. performance goal) were less likely to involve themselves in mathematical exploration (i.e. learning goal), and consequently this affected their decision to learn (Hannula, 2006). Also, Gilbert (2016) revealed that students with greater interest in mathematics and higher mathematics self-efficacy experienced fewer negative emotions, and their performance varied with the cognitive level required.

In short, motivation has a vital role in mathematics learning. The following part of this paper moves on to describe in greater detail motivation towards mathematics in the TEL environment.

4. Motivation towards mathematics in the Technology-enhanced Learning Environment

ICT has been used increasingly in mathematics education to enhance teaching and learning. It is intended that, along with these efforts, students' motivation towards mathematics would be improved as well. Therefore, it is important to ask what aspects of technology should be considered to enhance students' motivation, particularly towards mathematics learning in the TEL environment.

Erbas and Yenmez (2011) used a dynamic geometry software (i.e. Geometer's Sketchpad) to provide a computer-supported and student-centered collaborative inquiry learning environment to help elementary school students improve learning about polygons. The qualitative results revealed that students in the experimental group, unlike those in the control group, showed higher interest and motivation towards learning geometry based on the amount of time spent in the computer laboratory. However, the study also noted that the students' positive attitudes might be associated with the novelty effects of using technology (Erbas & Yenmez, 2011). Hannafin, Burrus and Little (2001) reported similar results where students' interest and attitudes towards geometry seemed to be changed positively during student-centered learning activities using dynamic geometry software. Nevertheless, their teacher observed that the novelty effects faded faster among lower mathematics proficiency students in the middle of the second week of the study (Hannafin et al., 2001). Therefore, it is important and necessary to take into account the possibility of novelty effects of technology wearing off by and to design strategies to sustain the motivation to learn mathematics.

Next, Kim et al. (2014) studied affective and motivational factors of learning in an online mathematics course. The results indicated that mathematics self-efficacy is a predictor of mathematics achievement, but that was not the case when achievement emotions (i.e. enjoyment or

anxiety) were considered in the virtual learning environment. Thus, it was suggested that since students' emotions play a part in motivation and achievement of learning, enhanced social presence could regulate their emotions and improve the cognitive process (Kim et al., 2014). The results supported those obtained by Clayton, Blumberg and Auld (2010) who found that most students, when asked to choose among traditional, online or hybrid learning environment, preferred a learning environment that matched their learning style, i.e. one that offered engagement and interaction with the teacher and fellow students. Therefore, it is important to recognise the need for social presence in the learning environment, especially for instance, in a technology-enhanced learning environment. This implies that technology (e.g. relational agent) could be leveraged to facilitate and regulate emotions to enhance motivation in the virtual mathematics learning environment (Kim et al., 2014). The computer artefact should be designed to build a socio-emotional relationship with users, in this case, to regulate emotions of the students in the virtual learning platform (Campbell, Grimshaw, & Green, 2009). The authors of this paper do not intend to review the relational agent in detail but to raise the point that technology might be able to afford opportunities to regulate students' emotions and motivation.

In another study, Star et al. (2014) examined technology-based strategies to enhance motivation in mathematics. Three technology-based strategies were used, each differing in terms of the type of motivation construct, the level of expenses, and technical sophistication. First, students were provided with an immersive virtual environment to promote self-efficacy by introducing game-like mathematical activities. Second, students were engaged in a web-based activity that did not contain any mathematical content but was aimed at changing their views on learning ability from fixed view of ability to incremental view of ability. Lastly, students watched a 56-minute mathematics-related video which could be considered an affordable and straightforward technological teaching tool, without any intention to improve any particular motivation construct. In terms of mathematics learning, the interventions had modest effects on students' mathematics scores which saw moderate gains (Star et al., 2014). Rather unexpectedly, students' self-efficacy did not improve significantly and students' incremental view of ability was found to be low (Star et al., 2014). The study highlighted the critical need to provide a motivational experience that could be adapted to the students' current developmental level (Star et al., 2014). Thus, it is suggested that an adaptive or individualized instruction is needed if technology is to be used as a motivational tool.

With regard to adaptive or individualised instruction, Foshee et al. (2015) used TEL to facilitate an individualised, adaptive, and mastery-based instruction for a college mathematics remedial class. TEL, in this case, was a highly developed software programme for mathematics learning. It is important to note that the adaptive instructions in the study referred to the process of determining the most suitable learning path for students by using thousands of data points that were from a constant assessment of students, and hence, individualised instructions were prepared for each student. The results showed that the adaptive TEL significantly improved remedial class students' mathematics scores as well as the perception of their ability in mathematics, which was conceptualised as mathematics self-efficacy. Foshee et al. (2015) concluded that repeated success experience had increased students' expectancy for success, thus changing their perception of their own mathematics ability. Surprisingly, students' motivation was significantly decreased, with motivation in this study being conceptualised as manifested behavior like participation in the class, being responsible for own learning and preparing for exams. Foshee et al. (2015) were of the view that the structure of the adaptive instruction system had lowered students' self-initiated behavior because the programme offered the learning path for them, i.e. making it easier for them to learn but not adequately motivating them. Thus, their motivation decreased. Nevertheless, Foshee et al. (2015) acknowledged the ability of TEL to improve students' self-efficacy.

Another technological tool, a 3-dimensional instructional game, was developed and used as a supplementary aid in mathematics lessons to improve students' achievement and motivation (Bai, Pan, & Kebritchi, 2012). The specially designed instructional game was aimed at enhancing motivation by stimulating students' curiosity, helping them develop a clear learning objective throughout the game, and encouraging them to be persistent in the process (Bai et al., 2012). The study revealed that while students subsequently increased their knowledge in algebra, there was only a slight increase in motivation for the treatment group, while motivation was decreased in the control group. Bai et al. (2012) argued that the results were in line with literature in that they

reflected students' refusal to learn mathematics when it got more difficult and it became a challenge to motivate students to learn mathematics.

Taken together, these results provide important insights into the motivation construct in the TEL environment. Apparently, the novelty effects of technology could be mistaken for motivation to learn (Erbas & Yenmez, 2011; Hannafin et al., 2001). More importantly, social presence is needed in TEL to motivate students as they need to interact with their peers in order to improve learning (Kim et al., 2014; Clayton et al., 2010). It should be noted that when mathematics achievement is improved with the integration of technology, it does not mean that that students are more motivated to learn (Kim et al., 2014; Star et al., 2014; Foshee et al., 2015; Bai et al., 2012). In other words, in the TEL environment, it is necessary to have strategies to improve and sustain motivation. However, there is no need to choose between scaffolding cognition (i.e. learning mathematics concepts) and motivation (Belland, Kim, & Hannafin, 2013). Specially designed adaptive instructional learning software could help remedial class students by providing motivating learning experiences and reinforcing their self-confidence when they experience repeated success (Foshee et al., 2015). Moreover, technology tools could also complement the teacher's role (Bai et al., 2012; Star et al., 2014) by providing a virtual learning environment where the instructor plays a supplementary role sometimes (Foshee et al., 2015; Kim et al., 2014). In either role, it is envisaged that technology could be leveraged to facilitate motivation towards mathematics.

5. Conclusion

In general, the literature suggests that technology is an effective tool for mathematics teaching and learning while potentially it can be a motivational tool as well. Nevertheless, whether or not technology can be used to enhance motivation in TEL depends on several considerations. For instance, the novelty effects of technology should be cautiously controlled in future research design to ensure that they do not affect the level of students' motivation in the long run. It should not be taken for granted that motivation will be enhanced when technology is used in mathematics learning. This implies the need for educators and policy-makers to understand and exploit the affordance of technology as a tool to improve mathematics instruction but not necessarily for motivating students to want to learn mathematics. It is also important to decide whether technology should play a supplementary or primary role in mathematics instruction at various levels of education, taking into account the motivational needs of students as well as the importance of social interaction in the classroom. In other words, the frequency and the extent to which technology would be used in classroom instruction should be complementary to the needs of students. The integration of technology itself cannot take care of motivation and learning in the TEL environment. The teacher or instructional designer should ensure that there is social presence as well so that learning can be meaningful and effective.

It is noteworthy that many studies have emphasized mathematics self-efficacy as one of the most critical motivational factors in mathematics learning. In this regard, TEL can be used to enhance students' self-efficacy, for instance, it provides repeated success in students' mathematics learning via adaptive software programmes. In other words, motivational factors in technology-enhanced mathematics learning can be improved by identifying students' present motivational problems beforehand. Instructional designers then can opt for the most suitable and available materials and tools for the instruction. Nevertheless, TEL should not replace the student's role in learning; self-initiation to learn and awareness about his or her own responsibility in the learning process are vital to building up motivation to learn. Therefore, TEL should be complementary to the student's motivational needs in the mathematics classroom. To conclude, while TEL has the potential to enhance motivation to learn, it is important to bear in mind its affordance as well as its efficacy as a supplementary or main instructional tool in the long run.

References

- Bai, H., Pan, W. H., & Kebritchi, M. (2012). Assessing the effectiveness of a 3-D instructional game on improving mathematics achievement and motivation of middle school students. *British Journal of Educational Technology*, 43(6), 993-1003.
- Bandura, A. (1994). Self-efficacy. In V. S. Ramachaudran, *Encyclopedia of human behavior* (Vol. 4, pp. 71-81). New York: Academic Press.
- Belland, B. R., Kim, C., & Hannafin, M. J. (2013). A framework for designing scaffolds that improve motivation and cognition. *Educational Psychologist*, 48(4), 243-270.
- Campbell, R. H., Grimshaw, M. N., & Green, G. M. (2009). Relational agent: A critical review. *The Open Virtual Reality Journal*, 1, 1-7.
- Clayton, K., Blumberg, F., & Auld, D. P. (2010). The relationship between motivation, learning strategies and choice of environment whether traditional or including an online component. *British Journal of Educational Technology*, 41(3), 349-364.
- Deci, E. L. (1972). Intrinsic motivation, extrinsic reinforcement, and inequity. *Journal of Personality and Social Psychology*, 22(1), 113-120.
- Erbas, A. K., & Yenmez, A. A. (2011). The effects of inquiry-based explorations in a dynamic geometry environment on sixth grade students' achievements in polygons. *Computers & Education*, 57, 2462-2475. doi:10.1016/j.compedu.2011.07.002
- Foshee, C. M., Elliott, S. N., & Atkinson, R. K. (2015). Technology-enhanced learning in college mathematics remediation. *British Journal of Educational Technology*, 1-13. doi:10.1111/bjet.12285
- Gilbert, M. C. (2016). Relating aspects of motivation to facets of mathematical competence varying in cognitive demand. *The Journal of Educational Research*, 109(6), 647-657. doi:10.1080/00220671.2015.1020912
- Gilbert, M., Musu-Gillette, L., Woolley, M., Karabenick, S., Strutchens, M., & Martin, W. (2014). Student perceptions of the classroom environment: Relations to motivation and achievement in mathematics. *Learning Environment Research*, 17, 287-304.
- Hannafin, R. D., Burrus, J. D., & Little, C. (2001). Learning with dynamic geometry programs: Perspectives of teachers and learners. *The Journal of Educational Research*, 94(3), 132-144. doi:10.1080/00220670109599911
- Hannula, M. S. (2006). Motivation in mathematics: Goals reflected in emotions. *Educational Studies in Mathematics*, 63(2), 165-178. doi:10.1007/s10649-005-9019-8
- Holmes, V. L., & Hwang, Y. (2016). Exploring the effects of project-based learning in secondary mathematics education. *The Journal of Educational Research*, 109(5), 449-463.
- Ismail, N. A., & Awang, H. (2012). Students' factors and mathematics achievement: Evidence from TIMSS 2007. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(3), 249-255.
- Keller, J. M. (2010). *Motivational design for learning and performance*. New York: Springer.
- Kim, C., Park, S. W., & Cozart, J. (2014). Affective and motivational factors of learning in online mathematics course. *British Journal of Educational Technology*, 45(1), 171-185. doi:10.1111/j.1467-8535.2012.01382.X
- Kirkwood, A., & Prince, L. (2014). Technology-enhanced learning and teaching in higher education: what is 'enhanced' and how do we know? A critical literature review. *Learning, Media and Technology*, 39(1), 6-36.
- Mullis, I. V., Martin, M. O., Foy, P., & Arora, A. (2012). *TIMSS 2011 International Results in Mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.
- OECD. (2014a). *In PISA 2012 results: What students know and can do- Student performance in mathematics, reading and science* (Revised ed., Vol. 1). OECD Publishing. doi:10.1787/9789264208780
- OECD. (2014b). PISA in Focus: Are grouping and selecting students for different school related to students' motivation to learn?. 1-4. doi:10.1787/5jz5hlpb6nxw-en
- Pantziara, M., & Philippou, G. N. (2013). Students' motivation in the mathematics classrooms: Revealing causes and consequences. *International Journal of Science and Mathematics Education*, 13, 385-411. doi:10.1007/s10763-013-9502-0
- Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivation: Classic definitions and new directions. *Contemporary Educational Psychology*, 25, 54-67. doi:10.1006/ceps.1999.1020
- Schiefele, U., & Csikszentmihalyi, M. (1995). Motivation and ability as factors in mathematics experience and achievement. *Journal for Research in Mathematics Education*, 26(2), 163-181.
- Skaalvik, E. M., Federici, R. A., & Klassen, R. M. (2015). Mathematics achievement and self-efficacy: Relations with motivation for mathematics. *International Journal of Educational Research*, 72, 129-136. doi:10.1016/j.ijer.2015.06.008

- Star, J. R., Chen, J. A., Taylor, M. W., Durkin, K., Dede, C., & Chao, T. (2014). Studying technology-based strategies for enhancing motivation in mathematics. *International Journal of STEM Education*, 1(7), 1-19.
- Tarmizi, R. A., & Tarmizi, M. A. (2010). Analysis of mathematical beliefs of Malaysian secondary school students. *Procedia Social and Behavioral Sciences*, 2, 4702-4706.
- Thien, L. M., & Ong, M. Y. (2015). Malaysian and Singaporean students' affective characteristics and mathematics performance: evidence from 2012. *SpringerPlus*, 4, 563-577. doi:10.1186/s40064-015-1358-z
- Walter, J. G., & Hart, J. (2009). Understanding the complexities of student motivations in mathematics learning. *The Journal of Mathematical Behaviour*, 162-170. doi:10.1016/j.jmathb.2009.07.001
- Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, 25, 68-81. doi:10.1006/ceps.1999.1015
- Yu, R., & Singh, K. (2016). Teacher support, instructional practices, student motivation, and mathematics achievement in high school. *The Journal of Educational Research*, 1-14. doi:10.1080/00220671.2016.1204260