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How tertiary learning advisors can support students engaged in online collaborative group work in large STEM courses

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Abstract

The article introduces Tertiary Learning Advisors (TLAs) in Aotearoa to several supportive strategies designed to engage students conducting collaborative group work online in large Science, Technology, Engineering and Mathematics (STEM) courses. The catalyst for this initiative was a learning design response to a largely amotivated and demotivated stage two STEM course cohort at the University of Auckland. Amotivation is a learner's realisation that either their current learning trajectory is too difficult or pointless, and demotivation is a specific trigger leading to amotivation (Dörnyei & Ushioda, 2011). The resulting intervention provided teaching staff with a robust methodology designed to re-engage students in this course. Understanding the challenges these students then experienced can enable TLAs in Aotearoa to more empathetically support students who are challenged by working collaboratively in large online STEM courses.

Keywords: STEM, online learning, collaborative, group work, challenges

Science, Technology, Engineering and Mathematics (STEM) education refers to the provision of opportunities for students to become self-confident, inventive, innovative, logically thinking, technologically literate problem solvers (Hasanah, 2020; Morrison, 2006). This is in response to an increasingly competitive global market defined by the need to guarantee and maintain adequate energy and productivity (Boe et al., 2011; Kelley & Knowles, 2016). Kubat and Guray (2018) believe the four STEM disciplines should be taught holistically as an undistinguished collective, whereas Hobbs et al. (2018) revealed various

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models of STEM implementation based on each discipline. When viewed as instruction, STEM education can be considered as a natural connection among STEM disciplines to further student understanding in each of them. This is achieved by broadening students' exposure to socially relevant contexts (Hasanah, 2020). Therefore, making STEM disciplines and career pathways more accessible and interesting for students (Wang et al., 2011) requires transforming related learning. McDonald (2016) summarised such requisite pedagogical adjustments as including inquiry, argumentation and reasoning, digital learning, computer programming and robotics, cooperative learning, assessment, and 21st century skills relevant in everyday life with potential for career development (Maarouf, 2019; Pawilen & Yuzon, 2019).

My first experience teaching STEM courses was to engineering cohorts at the University of Ulsan in South Korea. There, first year students had to complete a compulsory year-long course in English. In my seven years teaching such cohorts at that institution, I taught up to nine classes. Typically, seven were engineering majors. While students in those classes were invariably highly motivated, many struggled with collaborative group work assessments, which invariably occur in STEM course curricula. Their favouring of conducting tasks independently was due to cultural imperatives, particularly fear of loss of face or being seen to be openly engaged in disagreement with other group members. If these individuals were older, this could be perceived as challenging them, and this is unacceptable in Confucianism, which is the philosophy at the core of Korean culture (Jenks, 2017; Park, 2009). Related challenges included establishing an effective group hierarchy and associated roles with clear boundaries and expectations, and how to systematically execute given tasks. This may have been due to a lack of confidence and/or experience with how to present, defend, advocate, and respond to feedback (Bishnoi, 2017; Robinson, 2013).

These experiences would be called upon to inform my work as a member of the newly formed learning and teaching design team at the University of Auckland (UoA) in early 2020. As part of a re-structure, I was moved from my previous role as a learning and teaching development advisor, a position I had held since joining the UoA in 2019. The learning and teaching team's remit was to design courses and provide support to academics. Three members of this team, including myself, were allocated to a project tasked with providing a responsive methodology for a large STEM course which had received negative student feedback. Working collaboratively with faculty, the intent of the response was to empower it with a remedial learning and teaching methodology to initially replace twenty per cent of the course. The online collaborative learning literature which largely informed this project will now be introduced.

Literature Review

The Advantages of Collaborative Learning

There are many advantages of collaborative learning. Learning is influenced by interpersonal relations, social interactions, and communication with others, and learners need opportunities for positive interactive and collaborative tasks (Darnon et al., 2007). Research suggests that collaborative learning promotes critical thinking, which in turn promotes the retention of information by students for longer (Johnson & Johnson, 1986). It also promotes engagement in discussion, critical thinking, and the taking of responsibility for one's own learning (Toten et al., 1991). In online contexts, such collaboration promotes sustained task orientation and advanced knowledge construction (Schellens & Valcke, 2005). Other related advantages potentially include learners benefiting from exposure to diverse viewpoints from individuals with varied backgrounds, being challenged to actively engage with peers, and synthesising resulting new information into a framework of new knowledge over memorising it. Each viewpoint directly challenges learners to listen to differing views and to defend their own (Bishnoi, 2017).

Collaborative Learning in an Integrated STEM Learning Environment

An environment that is arguably conducive to collaborative learning is the integrated STEM learning one due to the learning of multiple disciplines. An integrated STEM learning environment can take place inside a programme through hands-on problem solving, which stimulates students to become more innovative and creative as disciplinary boundaries are broken down (Moore & Smith, 2014). Students have to apply multidisciplinary knowledge to solve real-world problems. By necessity, this creates conflict and disagreement, leading to reflection and adaptation (Robinson, 2013).

The Role of Technology in Facilitating Collaborative Learning in a STEM Environment

Given that STEM courses are invariably large, Yang and Baldwin (2020) advocate using technology to enhance the learning experience by providing authentic learning contexts, offering web-based inquiry environments, expanding learning through immersive and interactive technology, and transforming students from being consumers into creators (Salzman, 2013). Opportunities to support student learning in integrated STEM learning environments have greatly increased due to advancements in educational technology. By using immersive or interactive technologies, such as simulations, to facilitate learning multiple subjects simultaneously, remote subject content experts are brought into the classroom. They offset potential shortfalls in instructors' expertise in STEM subjects. They also accelerate student engagement and motivation through expanded experiences. They act as a supplementary resource and support collaboration and communication by facilitating active learning as technology provides a forum for discussions and writing (Mioduser et al., 2017).

Augmented and virtual reality technologies may increase students' feelings of immersion, thereby increasing their levels of understanding of STEM subjects (Restivo et al., 2014). This increases students' motivation as opportunities for authentic learning engagement can be derived from its use (Hsu et al., 2017). Technology is a means for students to acquire the skills of its use and to become engaged in related subject content (Yang & Baldwin, 2020). A core component of an integrated STEM learning environment is that it demands innovative practices including collaboration among instructors, subject experts, and students working together to solve real-world problems (Nag et al., 2013). Such an authentic approach promotes deeper understanding among students; however, implicit in this methodology is that the acquisition of the required skills takes time and patience, and perseverance may be challenging for students used to instant gratification (Demski, 2009).

Technology-enabled learning can alleviate some of the challenges associated with collaborative learning in an integrated STEM learning environment. Technology-enabled learning can help students to solve problems while learning about related concepts (e.g., sustainability). This can be used to integrate learning and use, and it can enable students to focus their attention and working memory on specific variables. In so doing, more robust learning can be facilitated and potential cognitive overload can be mitigated. Creating content with technology also allows learners to display projects, role-play, and engage in design challenges (Grubbs, 2013).

Challenges Associated with Online Collaborative Learning in a STEM Environment

Nevertheless, not all learners feel comfortable participating in a group setting online. Additionally, the cognitively taxing nature of trying to learn and apply multiple subject content simultaneously during problem solving may challenge students face-to-face or online (Lamb et al., 2017). Research comparing digital to traditional classroom instruction has yet to support a consistent advantage for online learning (Cheung et al, 2023). Importantly, for all that technology promises, it also harbours pitfalls if used in ways that do not align with what is understood about how humans learn (McKnight et al., 2016). In summary, while the conceptual view maintains that collaborative group work develops critical thinking and is a highly relevant soft skill that employers value, some students view it with hostility and/or apathy (Robinson, 2013). Indeed, some students see group work as emotionally and intellectually taxing (Burdett, 2003).

Differences Between Co-Operative and Collaborative Group Work Approaches

Why might some students feel this way? The answer may partly lie in the difference between co-operative and collaborative learning approaches. In co-operative learning environments, there is a division of labour between group members (Zhou & Colomer, 2024). This ensures each group participant is responsible for a particular aspect of the problem-solving exercise. In collaborative learning, however, the participants mutually engage in a coordinated attempt to solve the problem. In a collaborative group task, each member of the group needs to be interdependent to complete it. This can be particularly challenging for students who are only used to isolated learning, in which they compete with others and prefer passive rather than active learning. Some learners may prefer receiving instruction from an expert over those they perceive to be lacking in knowledge, and they may find themselves studying at a different pace from other group members, causing frustration for all participants (Lane, 2016). In online collaborative learning, strategies for the promotion of belonging and connectedness therefore become critical for learners. Of particular importance to students is social presence, or their perception of distance to each other and their instructors (So & Brush, 2008).

Students who experience difficulties as a consequence of doing group work online particularly note constraints on autonomy, as well as dependence on other group members and technology. Some cite the impersonality of working online with others they did not know and delays in progress (Robinson, 2013). Bishnoi (2017) details potential challenges of learning in this way, including certain individuals feeling uncomfortable, awkward, or shy participating even by distance, and the possibility that the group's focus becomes challenged or lost. Unequal group participation may be heightened by distance, and group members being unable or refusing to compromise, negotiate, or agree can be a significant issue if the project is collaboratively graded. The abundance of information generated by a group may be difficult to assimilate and compile within a given time limit and within the assignment constraints. For distance students, further issues can exacerbate any related dissatisfaction related to online group work, including unclear expectations from instructors, workload, poor software interface, slow access, and no synchronous communication (Gaddis et al., 2000). In summary, some learners may find online environments impersonal (So & Brush, 2008; So & Kim, 2005), resulting in low levels of engagement and participation and therefore less effective learning (Kear, 2010). However, students' poor time management skills, rather than technology, are a significant obstacle to collaborative group work satisfaction (Aycock et al., 2002). So, with all of this in mind, how might a Tertiary Learning Advisor (TLA) best support a learner engaged in online collaborative group work using technology in an integrated STEM learning environment?

Effective Collaborative Group Work Methodology

Marra et al. (2016) background an effective collaborative group work methodology used with third- or fourth-year engineering students at a large Midwestern public university in the United States. These authors created a combined pedagogical and technological environment to support collaborative problem-solving during a semester-long undergraduate engineering course. The collaborative group project required the students to identify a human factor problem and provide a solution over three phases: identifying and justifying the problem, selecting methods, conducting preliminary analyses, and redesigning and reporting on the final project. These authors developed epistemic and social scripts as prompting questions as scaffolds. These were shared inside each group. The prompts included 'What methods will we use to assess risks?' They were designed to deconstruct the analytical process while allowing students to monitor their own progress and receive feedback.

Wood et al. (1976) define scaffolding as providing expert assistance that enables learners to achieve what they could not do independently. Increasingly, software or technology-based scaffolds (e.g., Zahn et al., 2012) support such learning activity over reliance on intervention from instructors (Marra et al., 2016). While STEM-related collaborative learning increases academic achievement (Springer et al., 1999), Marra et al. (2016) make the point that managing conflict and unequal levels of participation among group members remain key challenges for learners. Additionally, students who are uncomfortable with online learning become further alienated by a lack of direct teacher input (Lamb et al., 2017). It is therefore important to note that technology-based solutions alone may be insufficient to support the development of some students' collaborative skills (McKnight et al., 2016).

The Case: Online Collaborative Group Work in a Large STEM Course

Due to negative student feedback, the Engineering faculty at the UoA sought remedial support from its learning and teaching design team for a stage two STEM course. After learning analytics were conducted, faculty and the learning and teaching design team agreed to replace twenty per cent of the course with a new methodology. This was specifically designed to address student demotivation issues while adhering to the requirements of the UoA graduate profile. The profile's latest iteration highlights the fostering of interculturally aware, inclusive, empowering, and service-minded graduates who build creativity and sustainability on past knowledge with a focus on the future (Waipapa Taumata Rau/University of Auckland, 2024). This graduate profile informed the resulting methodology, comprising four assessments. Individually, students performed an online ranking task. In groups, they repeated this task to form a single answer. In two fifty-minute tutorial sessions, groups were then assigned two 500-word report-writing assessments to complete collaboratively in the given time limits.

For these assessments, students were allocated into groups comprising four members. Individually, they viewed a 20-minute story produced by Whakaata Māori (Māori Television). This story investigated the environmental impact of intensive forestation on now erosion-prone land on the East Cape of the North Island of Aotearoa New Zealand. This had resulted in felled trees polluting rivers and the beaches. Interviewees included local hapu and iwi, farmers, small business owners, politicians, environmentalists, and industry representatives. As a drag and drop exercise, students were tasked with independently answering: If you were a forester assigned with the clean-up, how would you rank these stakeholders in order of importance? For the second assessment, each group repeated the process, corroborating a collaborative answer which was also submitted online. In the first 50-minute tutorial session, groups were then tasked with authoring a 500-word report for shareholders of the logging company on how, as foresters, they would remedy this situation. In the second allocated tutorial session, in a further 500-word report, students would respond to feedback from the CEO of the forestry company which rejected one aspect of their previous submission.

The rationale for this methodology was that technology-based scaffolded question prompts can greatly assist students to problem solve collaboratively (Marra et al., 2016). The use of immersive and interactive technology facilitated multiple aspects of learning about related concepts (e.g., sustainability) to occur concurrently. These included critical thinking, negotiation, and justifying, and they allowed for integration between learning and use (Grubbs, 2013). Such active learning provided a forum for discussions and writing through expanded supplementary tasks that accelerated student motivation and engagement (Mioduser et al., 2017). Creating content using technology also provided opportunities for groups to highlight engagement with their tasks (Grubbs, 2013). Key student challenges included:

- having little to no experience in applying multidisciplinary knowledge to solve real world problems that create conflict and require reflection and adaptation (Robinson, 2013),
- group members being interdependent of each other (Lane, 2016), and
- the abundance of information generated by the group making it difficult to complete assignments within assigned constraints (Bernard et al., 2000; Lamb et al., 2017; McKnight et al., 2016).

Interpretation of the students' experiences conducting these tasks will now be discussed.

Findings

The biggest challenges students in this cohort faced were all related to their inexperience in conducting collaborative group work. Because they had little to no requisite soft skills literacy or internal resources necessary to negotiate differences, this often caused delays. For many, needing to corroborate multiple, often conflicting, viewpoints into one response was an entirely new experience for them. As groups had a week to submit their ranking assessment, most were able to successfully negotiate a single, agreed-upon answer. However, when the added expectation of writing assessments needing to be completed within a strict time limit, some groups experienced management issues. These were related explicitly to forming and maintaining a functional group. Arguably, in some cases, the standard of written submissions may have reflected the impact of a resulting lack of time management. Specifically, the need to quickly focus on establishing a workable timetable and template for the initial writing task submission and adhering to it was underestimated. These factors were only intensified with their second writing assessment, with some groups struggling to achieve consensus on how to respond to the feedback in the time allocated.

For some students, the issues above were exacerbated by their perception of isolation. This was largely due to believing they had no roadmap or process to follow, and in its absence, a greatly reduced means of receiving teacher support in an online environment. Their perceived vulnerability is understandable. Because the tasks involved critical thinking – and therefore differences of interpretation – reaching consensus was often problematic without adequate soft skills literacy. For some, these issues were intensified by being online, resulting in some students reducing their level of participation or even disengaging. This made the process more difficult for some groups to manage. Therefore, an emphasis on prior exposure to, instruction in, and safe opportunities to develop soft skills use before engagement with related assessments in subsequent iterations was advised.

This methodology was arguably a significant improvement over what it replaced, particularly with its student-centred, real-world problem-solving focus using soft skills. While endorsing it, the faculty was acutely aware that with four teaching staff and four graduate teaching assistants (tutors), the support they wished to offer students could not realistically be provided. Given these limitations, it was decided that autonomous online self-study and assessment tasks would benefit students. These tasks related to grammar and report writing, with annotated exemplars and writing templates. Where possible, teaching staff visited groups online to monitor progress and offer feedback, particularly relating to challenges of establishing roles and negotiating within clear boundaries, compromise, and strategies to meet deadlines.

Regarding the latter, one strategy used involves tasking students with completing a simpler report-writing task than those in their assessments, to be taken with the same constraints of 500 words in 50 minutes. By a process of scaffolding, the exercise is repeated. Initially, the expectation is that the word limit is dropped to 450 words and finally to 350 words, without negatively impacting the content. Constructive feedback provides a means for students to write more quickly and economically. As students gain confidence in this task, the difficulty of it can be made incrementally more complex. This requires the student to work more efficiently and effectively to complete it (Dörnyei & Kubanyiova, 2014). Future iterations of this course could benefit from more guided instruction on how students manage group dynamics, particularly negotiating, effective compromise, resolving conflict, and working to deadlines.

Discussion

As the findings suggest, applying multidisciplinary knowledge to solve real-world problems can become problematic if the group's focus becomes challenged or lost (Robinson, 2013). Additionally, if members are unable to negotiate, compromise, or agree, lengthy delays result (Bishnoi, 2017). Poor time management skills may pose a significant obstacle to collaborative group work satisfaction (Aycock et al., 2002). For this cohort, these challenges may be more fully explained by a lack of a roadmap to negotiate collaborative group work and a corresponding lack of soft skills literacy required for it.

While collaborative learning promotes critical thinking, the retention of information (Johnson & Johnson, 1986), engagement in discussion, and the taking of responsibility for one's own learning (Totten et al., 1991), it also poses significant challenges. In this case, students were being exposed to diverse viewpoints which they had to respond to while at the same time defending their own (Bishnoi, 2017). Invariably, this created disagreement leading to adaptation (Robinson, 2013). As many of this cohort had only experienced isolated, competitive learning that was predominantly teacher-centered, they were presumed to have preferences for passive learning over active learning and for instruction from an expert over peers. For them, group member interdependence may have been challenging as they studied autonomously and at a different pace (Lane, 2016). These factors potentially caused frustration for all group participants that were exacerbated online (Lamb et al., 2017). However, while affected students may have anticipated being able to seek remedial teacher-led instruction, this can be greatly reduced in the online space (Lane, 2016). There, social presence, or the perception of distance to each other and their instructors, is of particular importance (So & Brush, 2008). This can result in certain individuals feeling uncomfortable participating (Bishnoi, 2017), reducing their participation, not engaging, or even withdrawing (Kear, 2010).

How might a TLA respond to these students? As Carter and Bartlett-Trafford (2008) state, a key role of TLAs is the scaffolding of professional and transferrable skills. This promotes autonomous learning and provides psychological and pastoral support for learners challenged by aspects of academic culture. TLAs can assist students in building supportive peer-based learning networks as participation in them is linked to positive changes in learning and study practices (Sotardi & Friesen, 2017). Once these are established, TLAs can contribute by modelling, replicating, and scaffolding the same methodologies required to complete collaborative group work in STEM courses. If students can see personal and professional relevance of such assigned tasks (Liu & Bridgman, 2023), they will be motivated to contribute (Dörnyei & Ushioda, 2011). The success of this approach is enhanced if these tasks are conducted in a safe judgment free environment, where students can receive immediate, constructive criticism throughout each step of the process (Dörnyei, 2005). Furthermore, if the selection of materials and resources is drawn from real-world examples that correlate with their coursework, this can stimulate engagement (Dörnyei & Kubanyiova, 2014). A scaffolded approach (Wood et al., 1976), initially face-to-face, offers students opportunities to seek feedback and model the strategies. Given that some students can be expected to face challenges in the online space (Bernard et al., 2000; McKnight et al., 2016), particularly when modelling such collaborative tasks online (see Bishnoi, 2017, and Robinson, 2013), active participation by a TLA can provide much-needed support.

Conclusion

As this article has demonstrated, in STEM environments where students are tasked with solving real-world scenarios, disagreement and the need for resolution through compromise invariably arise (Burdett, 2003; Robinson, 2013). Forming and maintaining functional groups to solve these problems under pressure (Demski, 2009) was the biggest challenge for the students in this case study. These challenges were exacerbated online in an environment where they were expected to work largely autonomously and teacher support was greatly reduced (Bernard et al., 2000; Lamb et al., 2017; McKnight et al., 2016). With knowledge of these challenges, TLAs can facilitate these students' safe practice of tasks and mitigate the issues they experience when trying to complete them. As Sotardi and Friesen (2017) note, students transitioning to university often feel unprepared. Without adequate, scaffolded instruction in the requisite soft skills required for this transition, they may remain illiterate in those that are at the core of STEM courses. As this article has argued, employing modified learning strategies can also lead to positive changes in students' learning and study practices. Regarding support for those working collaboratively online specifically, TLAs can now respond to students' related needs confidently through the understanding they have gained in this article.

References

Aycock, A., Garnham, C., & Kaleta, R. (2002). Lesson learned from the hybrid course project [Electronic version]. *Teaching with Technology Today, 8.* http://www.uwsa.edu/ttarticles/graham2.htm

Bernard, R. M., Rubalcava, B. R., & St-Pierre, D. (2000). Collaborative online distance learning: Issues for future practices and research. *Distance Education, 21*(2), 260–277. https://doi.org/10.1080/0158791000210205

Bishnoi, N. (2017). Collaborative learning: A learning tool advantages and disadvantages. *Indian Journal of Health and Wellbeing, 8*(8), 850–852.

Boe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: Young people's achievement-related choices in late-modern societies. *Studies in Science Education, 47*(1), 37–72. https://doi.org/10.1080/03057267.2011.549621

Burdett, J. (2003). Making groups work: University students' perceptions. *International Education Journal, 4*(3), 177–200.

Carter, S., & Bartlett-Trafford, J. (2008). Who are we? Aotearoa New Zealand tertiary learning advisors talk about themselves. In E. Manalo, J. Bartlett-Trafford, & S. Crozier (Eds.), *Walking a tightrope – The balancing act of learning advising: Proceedings of the 2007 Association of Tertiary Learning Advisors of Aotearoa New Zealand (ATLAANZ)* (pp. 39–61). ATLAANZ.

Cheung, Y. Y. H., Lam, K. F., Zhang, H., Kwan, C. W., Wat, K. P., Zhang, Z., Zhu, K., Chung, Y. K., & Yin, G. (2023). A randomized controlled experiment for comparing face-to-face and online teaching during COVID-19 pandemic. *Frontiers in Education, 8*, Article 1160430. https://doi.org/10.3389/feduc.2023.1160430

Darnon, C., Butera, F., & Harackiewicz, J. (2007). Achievement goals in social interactions: Learning with mastery vs. performance goals. *Motivation and Emotion, 31*(1), 61–70. https://doi.org/10.1007/s11031-006-9049-2

Demski, J. (2009). STEM picks up speed: The use of authentic scenarios to teach abstract concepts such as constant velocity is helping educators spark student interest in math and science. *THE Journal (Technological Horizons in Education), 36*(1), 22–26.

Dörnyei, Z. (2005). *The psychology of the language learner: Individual differences in second language acquisition*. Lawrence Erlbaum.

Dörnyei, Z., & Kubanyiova, M. (2014). *Motivating learners, motivating teachers: Building vision in the language classroom.* Cambridge University Press.

Dörnyei, Z., & Ushioda, E. (2011). *Teaching and researching motivation* (2nd ed.). Routledge.

Gaddis, B., Napierkowski, H., Guzman, N., & Muth, R. (2000). A comparison of collaborative learning and audience awareness in two computer-mediated writing environments. *Annual proceedings of selected research and development papers presented at the National Convention of the Association for Educational Communications and Technology*. Denver, CO. https://files.eric.ed.gov/fulltext/ED455771.pdf

Grubbs, M. (2013). Bridging design research and theory with teaching and learning. *Technology education for the future: A play on sustainability – Proceedings of the Pupil's Attitudes Toward Technology International Conference*. Christchurch, New Zealand. https://assets-002.noviams.com/novi-file-uploads/iteea/pubs/PATT27proceedingsNZDec2013-836793cd.pdf

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education, 16*(3), e2217. https://www.ijese.com/download/key-definitions-of-stem-education-literature-review-8336.pdf

Hobbs, L., Clark, J. C., & Plant, B. (2018). Successful students – STEM program: Teacher learning through a multifaceted vision for STEM education. In R. Jorgensen & K. Larkin (Eds.), *STEM education in junior secondary* (pp. 133–168). Springer Nature.

Hsu, Y. S., Lin, Y. H., & Yang, B. (2017). Impact of augmented reality lessons on students' STEM interest. *Research and Practice in Technology Enhanced Learning, 12*(1), 2. https://doi.org/10.1186/s41039-016-0039-z

Jenks, C. J. (2017). *Race and ethnicity in English language teaching: Korea in focus.* Multilingual Matters.

Johnson, R. T., & Johnson, D. W. (1986). Action research: Cooperative learning in the science classroom. *Science and Children, 24,* 31–32. https://www.jstor.org/stable/43166314

Kear, K. (2010). Social presence in online learning communities. *7th International Conference on Networked Learning,* Aalborg, Denmark. http://oro.open.ac.uk/21777/2/299A98F0.pdf

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *Journal of STEM Education, 3*(11), 1–11. https://doi.org/10.1186/s40594-016-0046-z

Kubat, U., & Guray, E. (2018). To STEM or not to STEM? That is not the question. *Cypriot Journal of Educational Sciences, 13*(3), 388–399. https://files.eric.ed.gov/fulltext/EJ1193465.pdf

Lamb, R., Akmal, T., & Petrie, K. (2017). Development of a cognition-priming model describing learning in a STEM classroom. *Journal of Research in Science Teaching, 52*(3), 410–437. https://doi.org/10.1002/tea.21200

Lane, S. (2016). Promoting collaborative learning among students. *American Journal of Educational Research, 4*(8), 602–607. https://doi.org/10.12691/education-4-8-4

Liu, D., & Bridgman, A. (2023). What to do about assessments if we can't out-design or outrun AI? University of Sydney. https://unisydmy.sharepoint.com/:b:/g/personal/danny_liu_sydney_edu_au/EVnXmBOhOMdOrA7_plQLh5kB5rwPKw7fPOAMYvS2FO682Q?e=ztgXRi

Marra, R. M., Steege, L., Tsai, C. L., & Tang, N. E. (2016). Beyond "group work": An integrated approach to support collaboration in engineering education. *International Journal of STEM Education, 3,* 1–15. https://doi.org/10.1186/s40594-016-0050-3

Maarouf, S. A. (2019). Supporting academic growth of English language learners: Integrating reading into STEM curriculum. *World Journal of Education, 9*(4), 83–96. https://doi.org/10.5430/wje.v9n4p83

McDonald, C. V. (2016). STEM education: A review of the contribution of the disciplines of science, technology, engineering, and mathematics. *Science Education International, 27*(4), 530–569. https://www.icaseonline.net/sei/december2016/p4.pdf

McKnight, K., O'Malley, K., Ruzic, R., Horsley, M. K., Franey, J. J., & Bassett, K. (2016). Teaching in a digital age: How educators use technology to improve student learning. *Journal of Research on Technology in Education, 48*(3), 194–211. https://doi.org/10.1080/15391523.2016.1175856

Mioduser, D., Nachmias, R., & Forkosh-Baruch, A. (2017). New literacies for the knowledge society. In J. Voogt, G. Knezek, R. Christensen, K. W. Lai, K. Pratt, P. Albion, & P. Resta (Eds.), *The international handbook of information technology in primary and secondary education: Part 2* (pp. 23–42). Springer.

Moore, T. J., & Smith, K. A. (2014). Advancing the state of the art of STEM integration. *Journal of STEM Education: Innovations and Research, 15*(1), 5–10. https://www.jstem.org/jstem/index.php/JSTEM/article/view/1917/1581

Morrison, J. S. (2006). *TIES STEM education monograph series: Attributes of STEM education.* TIES.

Nag, S., Katz, J. G., & Saenz-Otero, A. (2013). Collaborative gaming and competition for CS-STEM education using SPHERES Zero Robotics. *Acta Astronautica, 83,* 145–174. https://doi.org/10.1016/j.actaastro.2012.09.006

Park, J. S.-Y. (2009). *The local construction of a global language: Ideologies in South Korea.* Mouton de Gruyter.

Pawilen, G. T., & Yuzon, M. R. A. (2019). Planning a science, technology, engineering, and mathematics (STEM) curriculum for young children: A collaborative project for pre-service teacher education students. *International Journal of Curriculum and Instruction, 11*(2), 130–146. https://files.eric.ed.gov/fulltext/EJ1232759.pdf

Restivo, T., Chouzal, F., Rodrigues, J., Menezes, P., & Lopes, J. B. (2014, April). Augmented reality to improve STEM motivation. In *2014 IEEE Global Engineering Education Conference (EDUCON)* (pp. 803–806). IEEE. https://doi.org/10.1109/EDUCON.2014.6826187

Robinson, K. (2013). The interrelationship of emotion and cognition when students undertake collaborative group work online: An interdisciplinary approach. *Computers & Education, 62,* 298–307. https://doi.org/10.1016/j.compedu.2012.11.003

Salzman, H. (2013). What shortages? The real evidence about the STEM workforce. *Issues in Science and Technology, 29*(4), 58–67. https://issues.org/what-shortages-the-real-evidence-about-the-stem-workforce/

Schellens, T., & Valcke, M. (2005). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior, 21*(6), 957–975. https://doi.org/10.1016/j.chb.2004.02.025

So, H.-J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education, 51,* 318–336. https://doi.org/10.1016/j.compedu.2007.05.009

So, H. J., & Kim, B. (2005). Instructional methods for computer-supported collaborative learning (CSCL): A review of case studies. Paper presented at the 10th CSCL Conference, Taipei, Taiwan.

Sotardi, V., & Friesen, M. (2017). Student reflections on learning and studying during the transition to university: Implications for tertiary learning advisors. *ATLAANZ Journal, 2*(1), 19–35. https://doi.org/10.26473/ATLAANZ.2017.2.1/002

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69*(1), 21–51. https://doi.org/10.3102/00346543069001021

Totten, S., Sills, T., Digby, A., & Russ, P. (1991). *Cooperative learning: A guide to research.* Garland.

Waipapa Taumata Rau/University of Auckland. (2024). Graduate profiles: 2024 graduate profile. Waipapa Taumata Rau/University of Auckland. https://www.auckland.ac.nz/en/students/forms-policies-and-guidelines/student-policies-and-guidelines/graduate-profile.html

Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research, 1*(2), 1–13. https://doi.org/10.5703/1288284314636

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17,* 89–100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x

Yang, D., & Baldwin, S. J. (2020). Using technology to support student learning in an integrated STEM learning environment. *International Journal of Technology in Education and Science, 4*(1), 1–11. https://doi.org/10.46328/ijtes.v4

Zahn, C., Krauskopf, K., Hesse, F. W., & Pea, R. (2012). How to improve collaborative learning with video tools in the classroom? Social vs. cognitive guidance for student teams. *International Journal of Computer-Supported Collaborative Learning, 7*(2), 259–284. https://doi.org/10.1007/s11412-012-9145-0

Zhou, T., & Colomer, J. (2024). Cooperative learning promoting cultural diversity and individual accountability: A systematic review. *Education Sciences, 14*(6), 567. https://doi.org/10.3390/educsci14060567