SYSTEMATIC SCAFFOLDING AND FACILITATION IN ENGINEERING EDUCATION: A DATA-DRIVEN, PEER-MENTORED FRAMEWORK FOR TRANSFORMATIVE LEARNING

Sudha Kannurao*, Bryan Li, Chang Hark Loong, Guan Yin, Janessa Thng, Jillian Lee, Lie Siung Tjen, Pasan Bhashitha De Silva, Rudy Sabarudin, Soegeng Johari, Sojan Mary Joseph, Tan Kay Yew, Tanusree Adhikari, Yee Mei San

Temasek Polytechnic, Singapore

Sudha Kannurao* (sudhak@tp.edu.sg)

In contemporary classroom settings, where the students come from diverse educational backgrounds and possess varying learning abilities, the pace at which they grasp concepts differs significantly. Freshmen entering polytechnic institutions face considerable challenges in understanding the first year engineering courses, necessitating systematic scaffolding both within and outside the classroom. Recognizing this need, the Learning Support Programme (LSP) has been implemented in Temasek Polytechnic, School of Engineering (TP-ENG), for eight common engineering subjects, benefiting approximately 1000 students per semester.

The LSP is a structured and meticulously planned approach conducted outside regular timetabled hours. It aims to support students who struggle with conceptual understanding, thereby enhancing their performance in assessments and ensuring they keep pace with their peers. Dedicated facilitators, often the subject leaders, adopt a systematic method to ensure students grasp and apply engineering concepts effectively. The inclusion of senior students as peer mentors within the LSP framework fosters an interactive and collaborative learning environment. This peer-to-peer interaction enables mentees to gain clarity and confidence through engaging discussions and shared experiences.

Students' performance in the continual assessments provides feedback to the class tutors on their students learning and highlights areas where students are struggling. Automated workflow systems, utilizing Microsoft tools, issue timely email invitations to students identified as at-risk, ensuring proactive engagement. Furthermore, the LSP maintains records of attendance and participation, employing dashboard analytics to visualize student progress allowing for timely interventions and support.

As major assessments approach, the programme intensifies its support through focused tutor-based LSP sessions. These sessions offer tailored guidance on fundamental concepts, problem-solving strategies, significantly boosting students' confidence and preparedness for exams. Comparative performance tracking of invited students participating in the LSP against their non-participating peers consistently highlights the programme's effectiveness in improving academic outcomes and motivating students to participate in the LSP.

This initiative underscores the importance of structured, outside classroom support in bridging learning gaps and fostering a culture of continuous improvement. By leveraging pedagogical innovation, the LSP not only addresses immediate academic challenges but also contributes to long-term student retention and success in engineering education.

Keywords: *Learning Support Programme, Peer Mentoring, Data-Driven Interventions, Microsoft Power tools, data visualization.*

Introduction

Polytechnic education in Singapore is the vital component of post-secondary education that offers practical and career-oriented training. Education statistics digest (2021) reports that around 48 percent of students from post-secondary education are enrolling into polytechnic, of which around 4800 students enroll in engineering courses. Engineering diploma aims to prepare students for immediate employment or further studies, equipping them with applied knowledge, technical skills, and problem-solving abilities that align with industry demands. Transitioning from secondary school to polytechnic can be challenging for many first-year students as polytechnic education emphasizes self-directed learning, group projects, and critical thinking. This shift from a more structured and teacher-directed secondary school environment can be disorienting for students. Lim et al., (2008) highlighted that students accustomed to didactic methods may struggle with the open-ended, application-focused nature of polytechnic learning. Inadequate foundational knowledge in core subjects such as mathematics and physics also hampers their ability to grasp advanced engineering concepts. Hence the transition to polytechnic education requires students to adopt effective learning strategies.

A study by Zhang et al. (2024) involving 450 first-year engineering students found that students who improved their learning strategies demonstrated better academic performance. Apart from technical knowledge, students need to develop soft skills like the ability to communicate and work well in teams and managing workloads. Addressing these learning difficulties requires a multifaceted approach, combining curriculum adjustments, development of learning strategies, and institutional programs aimed at supporting students' academic and personal growth.

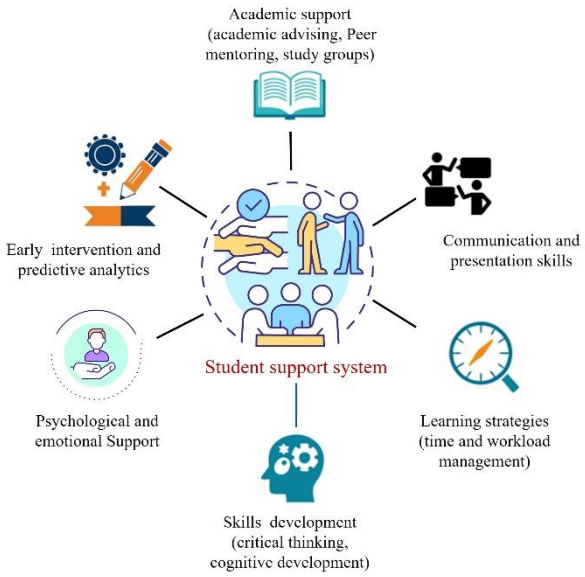


Figure 1: Student support system.

Support systems (Figure 1) that could help first-year students cope with the initial challenges include: (a) Access to knowledgeable academic advisors who can help students navigate their academic journey and address any challenges they encounter. (Robbins et al., 2012). (b) Offering one-to-one tutoring services where students can receive additional help with challenging subjects or concepts to improve learning outcomes (Dixson, 2010). (c) Pairing students with seniors who as their mentors, can provide guidance, support, and valuable insights into the engineering field (Kovacs et al., 2016). (d) Development of a predictive analytics model in early detection of students falling behind and provide targeted intervention (Low et al., 2024). (e) On-campus mental health support for stress, anxiety, low self-confidence, or academic pressure. (f) Conducting learning skills workshops in time management, note-taking, exam strategies, and critical thinking. (g) Providing training in technical report writing, reading technical lab manuals, and improving communication skills. Student support systems discussed in (e) to (g) apply to all the polytechnic students and hence those systems need to be implemented at the institution level. Strategies in (a) to (d) are more specific to individual disciplines and are suitable to be implemented at the school or subject levels. In this paper, we are sharing the subject level scaffolding and support offered to the first-year students in coping with the learning difficulties.

Pedagogy

The 3-tier Response to Intervention (RTI) model was formulated by Fuchs et al., (2008) as an educational framework aimed at early identification and support for students with learning and behavior needs (Figure 2). Tier 1 support is provided to all the students and is differentiated enough to meet all students needs and learning styles. Students who appear below grade level on academic screening assessments will often qualify for tier 2 intervention, which typically involves evidence-based interventions focused on specific content or skills, and some instruction in a small-group setting. Students who continue to perform below grade level on benchmark assessments and show little to no response to the tier 2 interventions, may then be found eligible for tier 3 intervention, which consists of either small-group, or in some cases one-to-one, instruction. Students who are enrolled in diploma courses in TP-ENG are from various academic backgrounds with different learning styles and abilities. Hence, apart from tier 1 support, students also need systemic scaffolding and support that is offered at tier 2 and tier 3 levels.

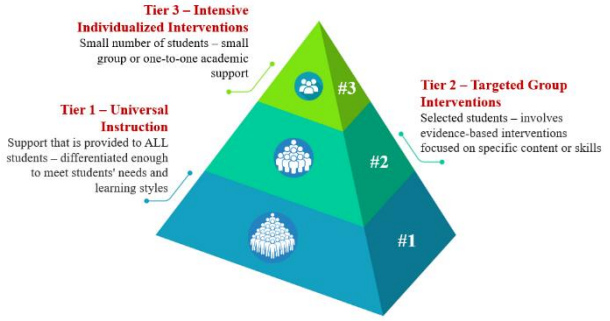


Figure 2: RTI tiered model.

Methodology

The pace at which polytechnic engineering diploma students understand the concepts during the classroom lessons varies among individuals. Some students may need more time and structured support during and after the classroom lessons. To assist students who require additional time and guidance to understand the concepts, the Learning Support Programme (LSP) was introduced in TP-ENG for first-year students. This programme covers eight core subjects and supports approximately one thousand students each semester. LSP sessions are scheduled outside of the timetabled lesson hours and are conducted by a couple of faculty members per subject who are also the subject leaders. LSP sessions are conducted via two approaches. Approach 1: Students who need help with the concepts are encouraged to attend the LSP sessions and clarify their misconceptions or seek help in better understanding of the concepts. Approach 2: Based on tier 2 of the RTI tiered model, selected students are invited to attend the weekly LSP sessions. Those students failing post-lesson quizzes are identified and email invitations are sent to them to attend the LSP sessions.

During the LSP sessions, the faculty member follows a structured lesson plan where the focus is on ensuring that the students get the concept correct and are also able to apply the concept to problem-based scenarios. Weekly LSP sessions provide the targeted small-group interventions to those students who are at risk and have not made adequate academic progress. As students are in small-group setup, they tend to be more open to discussions and seek clarifications from the faculty members. Small-group instructions or additional support with strategies focusing on specific skill gaps foster learning and in turn better academic performances. Timely short-term support and intervention help students comprehend the concepts more thoroughly, encouraging them to continue learning subsequent topics with ease. The effectiveness of LSP sessions stems from their data-driven approach and targeted support for selected students in need.

Apart from classroom-based learning, students in TP-ENG also attend hands-on practical classes where they relate the practical observations with the fundamental concepts learnt in the classroom. Weekly LSP sessions are also structured to support students who have difficulties with hands-on skills. During the LSP sessions, apart from getting support in conceptual understanding, students can also seek help with practical experiments.

Data-driven Targeted Group Intervention

Core engineering modules are offered to close to one thousand first-year students spread over forty plus tutorial classes with around twenty-five students in each tutorial class. Given the large cohort size, to save time and improve productivity, selection of students for the LSP sessions is automated using Microsoft tools like Microsoft forms and power automate applications. Figure 3 shows the selection process of students for the LSP sessions. Apart from selecting students for LSP sessions based on their post-lesson quiz performance, tutors can also identify students who may need more time and guidance in understanding the concepts. Students with special educational needs also benefit from the support provided to them during these sessions.

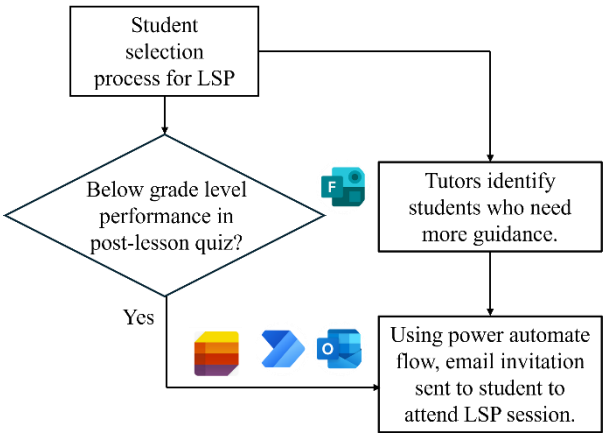


Figure 3: Student selection process for LSP.

Dashboard visualizations of students' post-lesson quiz performance are created using the Microsoft power BI app. Figure 4a and 4b shows the screenshot of dashboard visualization for Engineering Mathematics 1 and Circuit Analysis subjects, respectively. Selecting their tutorial class from the drop-down menu allows subject tutors to see their class's performance. Dashboard also shows the status of email invitations sent to underperforming students to attend LSP sessions (Figure 4a). Apart from showing the students' performance in the quiz, the dashboard also shows the overall confidence level of the students in understanding the concepts discussed during the lessons (Figure 4b). This provides tutors with feedback on student learning and highlights the concepts that require further explanation.

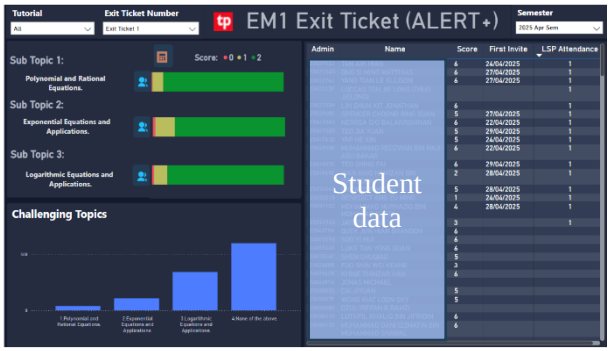


Figure 4a: Screenshot of the dashboard visualization of the post-lesson quiz analysis for Engineering Mathematics 1 (EM1).

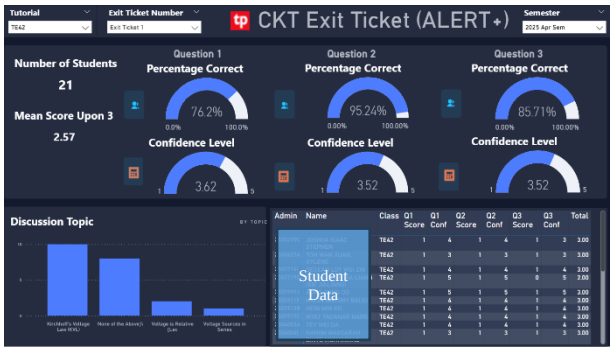


Figure 4b: Screenshot of the dashboard visualization of the post-lesson quiz analysis for Circuit Analysis (CKT).

During the LSP session, students scan a QR code to access a Microsoft form for recording their attendance. Microsoft power BI app retrieves the attendance data from Microsoft form to generate dashboard visualizations of students' attendance (Figure 5). Subject tutors retrieve student attendance data from the dashboard by selecting the academic year, semester, subject, tutorial class, and the date of the LSP session. With the data, which is also downloadable, tutors can closely monitor the student's learning progression and check on those who were invited for LSP sessions but failed to attend the LSP sessions.

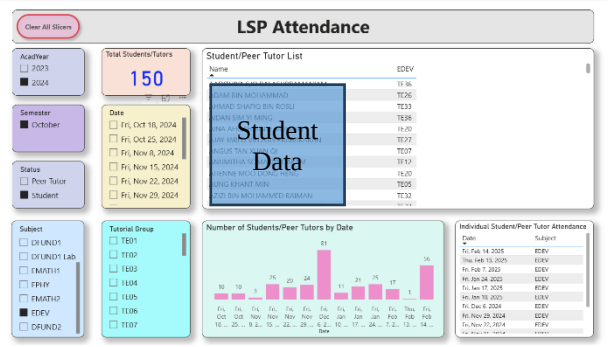


Figure 5: Dashboard for LSP attendance.

Peer Tutoring Programme

Under the Peer Tutoring Programme (PTP), senior students with high academic achievements are recruited as peer tutors. Peer tutors take on a mentoring role to assist students attending LSP sessions, either in small groups or individually. Structured lesson plan for the LSP sessions is shared with the peer tutors. They are also given training, so they are well prepared to guide the students during the LSP sessions. During the LSP sessions, at times, students may be intimidated to ask faculty members questions on fundamental concepts. However, students feel comfortable with the mentors and are open to discussing their learning difficulties and seeking advice from peer mentors. Apart from subject level guidance, peer mentors also share with students their academic coping strategies and provide them career guidance. The bond between the mentor and students at times, continues even beyond the LSP sessions. The inclusion of peer mentors into the LSP framework results in a collaborative learning environment.

Faculty members need to dedicate additional time to help students with special educational needs meet academic requirements. In such cases, a dedicated peer tutor is appointed to mentor and guide the student. This frees up the time of the faculty member who then can guide more students during the LSP sessions. Peer tutors are rewarded with co-curricular activities points for their contribution as peer mentors. To qualify for the points, peer tutors are expected to commit to certain number of mentoring hours per semester. Peer tutors' attendance is captured using the same QR code system that the students use to report their attendance for the LSP sessions. Peer mentor attendance data can be monitored using the LSP attendance dashboard as shown in Figure 5.

Enhanced LSP

In recent years, polytechnic is seeing an increase in number of freshmen with technical background coming from vocational schools. They possess strong practical skills but lack a solid foundation in Mathematics and Science. They have knowledge gaps in these subjects compared to students enrolled in polytechnic from mainstream secondary schools. Given the sizeable number of vocational school students, the weekly LSP sessions cannot accommodate everyone due to limited availability. Hence enhanced LSP system has been implemented that provides guidance within the timetabled hours unlike the weekly LSP sessions that are happening outside the timetabled hours. Ten tutorial classes were formed with students coming from vocational schools and the lesson plan was structured to cater to their learning needs. Apart from the integrated LSP within the timetabled hours, these students may also choose to attend the weekly LSP sessions offered to the rest of the cohort.

Tutor-based LSP

A week prior to major assessments, the weekly LSP sessions see a surge in attendance, with more students coming for support or to clarify their doubts. The faculty members along with the peer mentors are not able to handle the huge turnout. Hence, close to major assessments, the weekly LSP session is replaced with tutor-based LSP and is conducted by the tutorial class tutor for their own students who need more guidance on the concepts. Tutor-based LSP is made compulsory for students who are identified to be at-risk of failing the upcoming assessment. Tutors are also free to recommend students based on their assessment. During the tutor-based LSP, tutors provide guidance on fundamentals concepts; discuss problem-solving strategies which helps in instilling self-confidence in students to face the major assessments. Tutor-based LSP is conduced twice in a semester; one before the midterm assessment and another one before the end of the semester assessment. Subject leader: (a) prepares the lesson plan for the tutor-based LSP and makes it available for all tutors. (b) standardises the time slot for the respective subject. (c) makes venue arrangements for the tutor-based LSP. Attendance for the tutor-based LSP is captured using the same QR code as for the weekly LSP sessions.

Results and Discussion

Students attending LSP have benefited from the structured support provided to them outside of the timetabled hours which is evident from the subject satisfaction surveys done at the end of the semester. Students feedback that the additional support has helped them gain better understanding and reinforcement of the concepts and are able to do well in the assessments. Figure 6a presents the survey results on weekly LSP sessions for Digital Fundamentals 1 (DFUND1). 503 students participated in this survey conducted by the DFUND1 subject team.

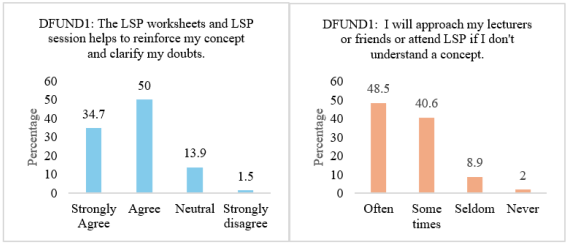
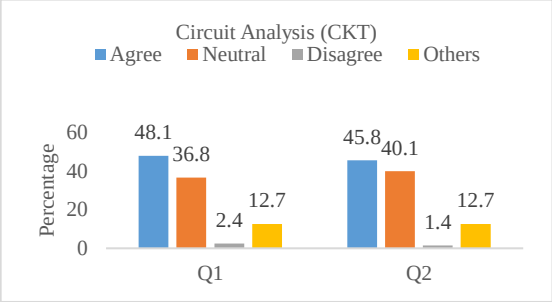


Figure 6a. Survey results (DFUND1).

Around 85% of survey participants either strongly agree or agree that the LSP sessions are helpful and when needed would seek help from the weekly LSP sessions. Figure 6b shows the survey results conducted by the Circuit Analysis (CKT) subject team on the effectiveness of the enhanced LSP. 212 out of 250 freshmen enrolled into enhanced LSP participated in the survey. Close to 85% agree that the enhanced LSP sessions help them in understanding the concepts better and are willing to attend LSP to seek help in their academics.



Q1: When I need help, I attend CKT LSP sessions, and they are helpful.
Q2: LSP questions discussed during the tutorial session helps me in understanding the concepts better.

Figure 6b. Survey results (CKT).

The effectiveness of the tutor-based LSP was evaluated by analyzing the subject-wise performance of students who were invited to participate. Students who were invited and attended the LSP sessions had a higher pass percentage than those who were invited but did not participate. Tracking of similar data for all the eight subjects over few semesters has also shown similar enhanced performance in the major assessments with almost 50% decline in the failure grade for those who attended the tutor-based LSP.

Like the performance analysis for tutor-based LSP, a study was done to check the effectiveness of the enhanced LSP. Data shows that the percentage of passes in all subjects for the students under enhanced LSP has improved. Apart from passing, their average scores have also improved consistently over the past few semesters.

Conclusions

Since the implementation of LSP in 2010 at TP-ENG, studies have shown that there has been significant enhancement to the academic performance of those freshmen struggling with core engineering subjects. By systematically identifying at-risk students through data-driven methods, the LSP provides targeted support outside regular class hours, ensuring these students receive the necessary guidance to grasp complex concepts. Enhanced LSP provides the much-needed support to the first-year students from vocational schools. Additional teaching resources are allocated for this implementation as enhanced LSP is integrated into the timetabled hours. The integration of peer mentoring within the LSP framework fosters a collaborative and supportive learning environment, where senior students guide their juniors, making the learning process more interactive and less intimidating. Automated administrative processes, utilizing Microsoft tools, streamline the selection and invitation of students, ensuring timely and proactive engagement. The programme's success is evidenced by improved academic outcomes and positive student feedback, highlighting its role in addressing immediate learning challenges. The LSP's structured approach, combined with innovative pedagogical methods, not only supports students academically but also helps them develop essential skills for their future careers. As the programme continues to evolve, it remains a vital component of Temasek Polytechnic's commitment to providing comprehensive support to its engineering students, ensuring they are well-equipped to meet the demands of their academic and professional journeys.

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