

# Out-of-Class Mathematics Support for Engineering Students

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## CONTEXT

Students enter undergraduate engineering degree programs with a wide range of mathematical knowledge, skills, aptitudes and abilities. A significant proportion of engineering undergraduates struggle with course mathematics requirements. Student pass / fail rates in engineering maths show that QUT's BEng students are no exception. QUT provides out-of-class support to students needing extra assistance with their maths (at point-of-need) via our STIMulate program. Difficulty dealing with the mathematics requirement of engineering courses is known both anecdotally and via a body of published research, to be a major contributor to students failing to complete their degree.

## PURPOSE

QUT's STIMulate program philosophy of support-for-learning embraces a social justice framework, student leadership, student-academic partnerships, peer assistance and facilitated learning. The STIMulate program has developed a series of complementary approaches to support academic success. The success of the program can be attributed in part to this combination of approaches and to a deliberate move away from the deficit model so often associated with learning support. The program has proven to be of value to large numbers of students with a range of mathematical knowledge, skills, aptitudes and abilities.

## APPROACH

Since 2013 STIMulate has supported student learning in maths, science and IT at QUT. It is a service founded on sound pedagogical practice. QUT's STIMulate program offers a multi-faceted approach of support to all coursework students (both undergraduate and postgraduate). It aims to enhance student learning, to increase capabilities and confidence in mathematical and scientific concepts, as well as to expand information technology skills and competencies. A well-developed consultation framework enables our STIMulate service to integrate with, complement and support QUT's curriculum. STIMulate uses sophisticated planning techniques that accurately predict levels of student demand at different stages of the upcoming semester.

## RESULTS

Evidence of the positive impact of STIMulate can be found in student grades, retention (attrition), lecturer feedback, client attendance figures and student client feedback (both anecdotal and via planned survey responses). On all measures for 2015 and 2016 (GPA, academic success, retention, attrition) students who attended STIMulate achieved better outcomes than those who did not. It is particularly pleasing to see a significant proportion of students from target equity cohorts taking advantage of our STIMulate service.

## CONCLUSIONS

QUT's STIMulate program offers a model of how to optimally organise and deliver support for mathematics learning. It demonstrates how academics and students can effectively partner to deliver a quality service.

## KEYWORDS

Engineering Mathematics Support; Peer Tutoring; Out-Of-Class Support; Support for Learning; QUT STIMulate.

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## **Engineering Mathematics Requirement vs. Student Mathematical Ability**

The literature is full of examples of how challenging students find engineering maths.

Many engineering degree programs in the UK run diagnostic test screening of commencing undergraduate mathematical ability in order to identify potentially 'weak' students early and to offer these 'at-risk' students additional support (Perkin & Bamforth, 2011). Mathematical ability diagnostic testing of commencing engineering students can also be found in Irish and Portuguese undergraduate degree programmes (Carr et al., 2015).

Tolley, Blat, McDaniel, Blackmon, and Royster (2012) report the US experience (spanning decades) is that there is a strong relationship between mathematics performance and retention of engineering students. They also point to evidence from across the US college system that nearly half of engineering freshmen would benefit from some mathematics remediation.

In Australia, the UQ student failure rate in 2013 was reported to be 30% for MATH1051, a first-year single variable calculus and linear algebra course (Hillock, Jennings, Roberts, & Scharaschkin, 2013).

## **Engineering Mathematics at QUT**

In common with the experience of many Bachelor of Engineering programs reported in the literature, a significant proportion of engineering undergraduates at QUT have difficulty passing the foundation courses in engineering mathematics. Across the six mathematics units (two compulsory and four elective) offered in QUT's BEng program STIMulate saw an aggregated failure rate of 24% (measured over three semesters 2015-16). For the same three semesters, Introductory Engineering Mathematics (the bridging unit for those without year 12 advanced level mathematics) the failure rate ranged from 11% up to 31% (averaging 21%). For the compulsory unit, Engineering Computation, there was a failure rate ranging from 19% up to 31% (averaging 25% when measured over three semesters 2015-16).

## **Institutional Support for Students of Mathematics**

A common response to the 'mathematics problem in higher education' defined as a "gap between the expectations and reality of the mathematical competence of new undergraduate students ..." (Kent & Noss, 2003, p. 9) has been the establishment of what are generally referred to as 'mathematics support centres'. A 2007 study (MacGillivray & Wilson, 2008) found that at least one such centre existed at that time in 32 of 37 Australian universities and a recent brief analysis of web page search results in the \*.edu.au domain indicates such centres / facilities continue to exist at many Australian universities. The third iteration of a Loughborough-led survey of 119 UK universities charts a growth in provision of mathematics learning support from 46 universities in 2000; to 66 in 2004; to 88 universities in 2012. This survey also found that mathematics support was just as likely to be provided at UK elite universities (the Russell and the 1994 groups), those with highest matriculation entry requirements (Perkin, Croft, & Lawson, 2013, p. 168).

## **QUT'S STIMulate Program**

### **Support for Maths, Science and IT Learning at QUT**

Since the early 2000s, QUT has provided intentional out-of-class maths support for engineering students (MacGillivray, 2009). In 2013, this QUT Maths Access Centre gave birth to the STIMulate program. STIMulate offers multi-faceted support to all coursework students (undergraduate and postgraduate). It aims to enhance student learning, to increase capability and confidence in mathematical and scientific concepts and to build student information technology proficiency and skill.

STIMulate differs from stand-alone programs offered at other universities. This is an integrated approach which meshes with the curriculum. It also differs in that it provides complementary methods of support (see the following section on program design).

QUT's program caters for diverse student ability and ambition by complementing units taught and by coordinating with teaching academics. Clients range from the struggling student, who wishes to pass, to the high-achieving student, who aspires to excel. This is point-of-need assistance, open and accessible. STIMulate delivers a supportive learning environment, fosters help-seeking behaviours, promotes independent learning and caters for diverse learning needs.

## **Program Design**

Operational funding for QUT's STIMulate program derives from the Student Services and Amenities Fee (SSAF) paid by all coursework students.

The team that supports student learning comprises some 150 trained volunteer students and nine academic staff who work in three complementary modes:

1. One-to-one support – predominantly peer-to-peer support but supplemented with one-to-one consultation time with staff, if required;
2. Group support – normally delivered by the academic staff in situations where a common need is identified; and
3. Virtual support – using e-mail, social media and online resources.

High-performing students are invited to join the team after they have completed at least one year of full-time study in a discipline area where need exists. They are provided training and support to equip them as Peer Learning Facilitators (PLFs).

The less formal nature of support provided to students by their student peers is designed to complement and coordinate with that provided by STIMulate academic staff.

## **STIMulate's Theoretical Paradigm**

The impact of programs like STIMulate can be difficult to measure using traditional evaluation approaches. A theoretical evaluation framework was developed in order to monitor our program. We adopted a Program Logic Model based on the approach used by the Kellogg Foundation (2006). The Kellogg Logic Model is commonly used to evaluate not-for-profit, community-based programs. Subsequently, our STIMulate Program Logic Model was developed in consultation with a diverse group of key QUT stakeholders. We achieved consensus amongst those stakeholders on what an ideal future design for our program would look like. The STIMulate Program Logic Model is used to compare the current situation with the ideal design and informs the plan that guides the program toward an ideal future.

## **Philosophy Behind the Service**

There are a number of underlying philosophies to the STIMulate model. They are:

### **Social Justice**

STIMulate operates under a social justice framework (Nelson & Creagh, 2012). Emphasising access, equity, rights and self-determination of participants, this framework forms the cornerstone of the program. STIMulate values the student perspective and prioritises access to the service for all students. Open access to the service for QUT students defines the design of learning environments to be welcoming and to cater for different needs. It also shapes a program that encourages participation by students across a spectrum of ability.

## **Student Leadership of the STIMulate program**

Student volunteers are integral to the delivery of QUT's program. PLFs provide much of the drop-in support and contribute to the operation and strategic direction of the program through regular team meetings. Senior PLFs are elected to serve on the STIMulate Student Executive Team. The leadership roles are viewed as educational opportunities for PLFs.

## **Support-for-Learning, rather than Learning Support**

The educational philosophy of STIMulate is based on support-for-learning, rather than learning support. This helps to reduce any stigma associated with remedial support and also emphasises the broad range of academic support to include all academic ability levels. The philosophy and culture encourages help-seeking behaviour and a collaborative learning environment.

## **Learning Facilitation, Not Tutoring**

Some students can be demanding and expect assignments to be done for them or to have their assessment checked. STIMulate does not give answers. It facilitates learning.

Every effort is made in promotion and marketing to differentiate this program from a tutoring service. Our philosophy is that the support is short-term and that students are assisted to become independent learners, progressing to interdependent learners (helping each other). Students who visit STIMulate attend 2.3 times per semester on average (mean), which is considered a healthy level of engagement by the STIMulate staff. The STIMulate 'Traffic Light System' defines the level of student support permitted by lecturers for assessment pieces.

## **Service Governance**

An advisory committee with members drawn from relevant faculties and other divisions provides strategic guidance to the program. Committee membership includes Assistant Deans (Teaching & Learning) from both the Health and the Science and Engineering faculties and eminent teaching academics. This committee meets five times a year and is chaired by the Director of Library Services.

Input from the volunteer student team also contributes to the direction of the program. These students come together each semester at a forum and awards presentation. The forum provides an avenue to discuss a range of topics helping to provide strategic and operational direction for the program.

At a more operational level, STIMulate staff, the Student Executive and stream teams meet on a regular basis.

## **Service Delivery**

STIMulate is coordinated centrally by QUT Library (part of QUT's Division of Technology, Information and Learning Support). Whilst STIMulate academic staff are employed via the Library, they operate out of the Science and Engineering Faculty (SEF). This helps build robust links and partnerships with key SEF academics, most notably with the School of Mathematical Sciences. Regardless, STIMulate welcomes and supports students enrolled in each and every faculty.

## **Types of Help Students Seek**

Typical prompts for students to seek support are for a need to understand lecture material, complete assignment tasks or prepare for examinations. Students typically seek maths support from STIMulate for topics such as differential equations, regression analysis, conditional probability and rearranging algebraic expressions.

## Operational Plan

### Mapping the Units

Before each semester STIMulate creates a plan to direct support to where we know or anticipate there will be a need. This unit mapping is a systematic approach to plan for support of the maths, science and IT learning needs of students. We believe mapping / planning greatly contributes to achieving a high-quality service that supports student success. STIMulate is a service delivered via an effective and efficient system. The program uses historical attendance data, unit plans and intelligence from students and academic staff. This leads to a series of detailed plans that map the topics covered, assessment items and the appropriate strategies for support, including learning resources. This plan is communicated to the staff and PLFs to ensure that the team is well-prepared. The map / plan initiates conversations with unit and course coordinators, other support-for-learning providers, and amongst members of the STIMulate Team. It enables predicted learning needs 'hotspots' to be adequately resourced. The unit mapping is also used to plan the promotion of the service to target cohorts, at optimal times.

### Traffic Light System

The map incorporates a 'traffic light system' that informs staff and PLFs as to the level of help and assistance that can be offered for assessment (without compromising the integrity of that unit's assessment). This traffic light system is developed in consultation and dialogue with teaching academics. Green light means facilitated learning can be provided. Amber (our default level) means limited assistance. A red light means no, or very little, direct help and assistance can be given, only general learning / organisational skills and advice.

Student clients keep abreast of activities week-by-week via posts on both Blackboard and Facebook. This includes being able to view published rosters when PLFs are available, their area of expertise and the timetable for any group support session.

### One-To-One Support

#### ***Drop-In Support (Mostly Peer-to-Peer)***

STIMulate is best known for its drop-in support. Students can drop-in to one of the STIMulate spaces without requiring an appointment and assistance. Ideally this happens when someone with the required expertise is on duty. Rosters are posted on the STIMulate Blackboard site.

When a rostered PLFs become unavailable (due to heavy assessment or illness), STIMulate's private social media channel alerts other PLFs of the vacancy. Failing that one of the academic team will fill the gap or a group support session is offered. A range of online resources, such as short student created videos of frequently asked questions, are being developed to assist students who are unable to receive face-to-face support for different reasons.

It is important to note that drop-in support is not tutoring. The PLFs are actively discouraged from tutoring, which is seen as more of a long-term arrangement, on a regular basis and where there is more of a teaching element than the facilitation of learning.

#### ***Student – Staff Consultations***

There are situations where booked time is organised with staff members. This approach is used where special needs or specific expertise exists, such as with a student with a hearing impairment in a quiet space or where a long-term plan is required.

### Group Support Workshops

The support provided to students in high-demand units is scalable through the provision of group support sessions. Group support sessions account for 45% of the total STIMulate

attendance and of these 65% are for mathematics support, predominantly for engineering students.

These sessions operate as a student-directed interactive workshop. The sessions are normally run by the STIMulate academic staff, and occasionally with PLFs. The provision of this support is also dynamic and responsive to the needs of students. Where possible, additional group support sessions are scheduled to respond to additional demand.

## **Online Support**

### **Blackboard**

STIMulate operates a Community Blackboard site. This hosts program information, published rosters, internally produced learning resources, plus links to high-value external learning resources.

### **Facebook**

Students can request assistance via the STIMulate Facebook site, often as a mechanism for identifying the support that might be available. The private STIMulate Facebook site is used by the student volunteers to coordinate the program delivery and create community.

### **e-mail**

Requests for support also come from students via e-mail. Assistance is occasionally provided through this format; however, e-mail questions normally lead to a referral to one of our other services.

## **STIMulate Student Client Profile and Personas**

During the 2015 academic year, 878 students enrolled in the BEng program participated in a drop-in support session. BEng students (including double degree students) taking advantage of a STIMulate offering made up 29% of total attendees (drawn from across the university). In 2015 of all undergraduate engineering student attendances at STIMulate 57% sought assistance with their understanding of mathematical concepts.

Attendance figures show a spread of academic ability levels; however, those who need more support come more often. The program caters for diverse student abilities and ambitions – from struggling students who desire only to pass, to high-achievers who wish to excel. Students with a GPA around a pass level (GPA 3 – 4) account for 14% of students and attend an average of 3 times per semester. Mid-range students (GPA 4.5 – 5.5) account for 51% of students and attend an average of 2.4 times per semester. High achieving students (GPA 6 – 7) account for 34% of participants and attend an average of twice per semester. The support required across this academic range is diverse and is accommodated in the pool of expertise of staff and PLFs.

The clients are not only struggling students in need of help. A good proportion are high achieving students (those with a GPA >6 who aspire for a top grade of 7). Many have a competent grasp of the concepts; however, they present at STIMulate seeking confidence and reassurance that their understanding of the concept is sound. Encouraging positive help-seeking behaviour for successful students helps to overcome any perceived stigma with any struggling student needing to access remedial support.

Although STIMulate supports all coursework students, students in their first year of study are the main clients accessing support. First year students account for 74% of all students who attend STIMulate. Attendance is also much higher at the beginning of the year, reflecting the high intake of new students, and the passage of commencing first year students transitioning to university life.

Compared against the overall QUT population a significantly higher proportion of students drawn from most of QUT's equity target groups took advantage of a STIMulate service. Most

notably these were students categorized as one (or more) of: *Non-English Speaking Background; Low Socioeconomic Status; With a Disability; Enrolled from a Regional Area.*

Research by STIMulate academics has identified typical personality traits, attitudes and motivations of students who use the service (Sankupellay, Niesel, Medland, & Mealy, 2015), developing a typology of seven student client personas. This research has enabled a better understanding of the characteristics and needs of student clients and it has informed the training of our PLFs and academic staff.

## **Staffing the Service**

### **Academic and Professional Staff**

QUT's STIMulate program employs nine (9) academic staff (6.1 FTE) and two full-time support staff. These academic staff guide, mentor and coordinate volunteer students. There are three academic staff allocated to each of the three streams — maths, science and IT. The load is greatest on the maths stream (39% of total academic staff workload) indicative of student demand.

A Student Support Officer coordinates student volunteers. This assists in the management of day-to-day operations of the program.

### **Student Volunteers**

Significantly, there are now have more than 150 students volunteering their time and expertise to provide the all-important drop-in support component of our program. They collectively volunteered 4,806 hours in 2015; assisting at 3,163 sessions; having supported students enrolled in 242 units.

The need to predominantly support first year students is well-matched and met by expertise of the PLFs. PLFs have completed at least one year of study and achieved at least a distinction in the areas they support. The expertise coverage required to support students in higher years of study needs to draw from both the staff and more advanced PLFs.

Student volunteers, known as Duty Hosts, also provide a concierge service to greet visiting students and refer them to the appropriate STIMulate services and other learning providers, as required.

The valuable contribution of these volunteers is recognised by the program at the end-of-semester awards presentation and by the university through contributing to students' co-curricular records.

## **Program Monitoring**

### **Regular, Open Communication with Teaching Academics**

STIMulate has close working relationships with QUT's teaching academics, taking direction from unit coordinators and historic program data to develop a support plan. The program operates at 'arm's length' from faculties however. It assists students whilst maintaining individual student confidentiality. STIMulate does provide anonymized cohort data back to lecturers as part of our feedback loop. This has proven to be valuable information which informs lecturers of issues within their units, allowing them to be addressed in a timely manner.

## **Evaluation of Impact**

The STIMulate program contributes to student success; however, it does not claim that student success is the direct result of our support service. Here a traditional evaluation approach is problematic. Causality is difficult to prove.

The evidence on the positive impact of STIMulate is based on student grades, retention (attrition), lecturer feedback, client attendance figures and student client feedback (both anecdotal and via planned survey responses).

On all measures for 2015 and 2016 (GPA, academic success, retention, attrition) students attending STIMulate have achieved a better outcome than those who did not. It is particularly pleasing to see a high proportion of students from target equity cohorts taking advantage of our STIMulate service.

The aim is to destigmatize the notion of asking for help. These positive results could partly be due to the fact that students attending our STIMulate service had a positive help-seeking experience, at their point of need. Students learn how very beneficial it can be to take advantage of this and of other university support services.

There are three ways that our program is evaluated to measure impact:

### **1. Attendance Data**

STIMulate aims to provide support when it is required rather than achieving high attendance figures. Nevertheless, participating engineering students attend STIMulate an average (mean) of 2.2 times per semester. In 2015, the maximum number of visits was eight (8) visits in one semester. These are considered healthy participation levels for the program. These return rates, together with increasing attendance figures since 2013, is an indication of program success. In an age where student class attendance rates are falling, the fact they come to STIMulate implies that they value the service.

### **2. Anecdotal Student Feedback**

Student clients regularly provide informal comments and feedback the STIMulate service via Facebook and e-mail. They are overwhelmingly favourable and positive. The following is representative feedback from students relating to drop-in support for engineering:

*"I'm extremely grateful for the help I received today. I couldn't understand what a question was asking me to find but [name withheld] helped me make sense of the wording".*

*"Calm and well explained... Let me talk myself through the problem. Thanks."*

*"Great help with working through using Matlab and graphically representing data".*

*"It was good. Having someone to bounce my ideas off who has a greater understanding of the content was incredibly beneficial for me to work through troubleshooting my problem".*

*"The video shown to me was very helpful and should be shown to others".*

*"Helped by showing me [how] to remove one line of redundant code :-)"*

### **3. Student Evaluation Survey Response**

Students attending STIMulate services are surveyed each semester to gauge the value of the program. From 2013 to 2015, these surveys were paper-based and administered to all students who made use of the service in Week 7 of the semester. In 2016, the survey moved to an online survey in Week 14 using the new support-for-learning evaluation framework.

The original Week 7 survey was completed by all students attending drop-in and group support. Almost all students (94%, n=133, Semester 1 2015) reported that they found the service useful and would come again.



In 2016, a more detailed online evaluation was implemented. Due to sub-optimal timing, however, there was a low response rate (drop-in support 4.6% and group support 3.3%). Despite this, the results were pleasing. Students overwhelmingly reporting improved academic capabilities, motivation and resilience (see Appendix 1 – Student Client Survey Feedback). Modifications to the design are likely to improve the response rate for similar evaluations in the future.

## **Future Directions**

The current program provision has proven successful; however, there are a number of aspects of the STIMulate program which are being strengthened and developed. These planned changes aim to improve STIMulate for students using the service and assist student cohorts not currently accessing support.

Part-time students and distance students rarely access STIMulate services. This is mostly due to their limited time on campus. Although the option of providing a face-to-face synchronous support via a video chat application has been explored, the logistics of organising scheduled sessions has proven difficult. One strategy now being explored is to develop a series of videos on frequently asked questions. These video resources (being produced by PLFs) focus on topics where no quality external alternative exists on the web. This approach also curates the knowledge base and is made available to any student requiring assistance, at any time, allowing students to view these sessions as many times as required. Similarly, the establishment of online discussion forums is being explored. This would allow assistance to be provided to many by many.

There have been many discussions on developing an integrated reporting platform whereby summative data on the support being provided by STIMulate and other support services could be readily available to any stakeholders. This would enable timely feedback to the academic community and other interested parties on the level of support being provided to various student cohorts. STIMulate drop-in support data already exists in a corporate data warehouse. However, planned improvements to the bookings system for consultations and group sessions will allow a more complete picture of the support being provided in a timely manner.

## **Conclusion**

With an ever-increasing corporate knowledge about students requiring support, more strategic and proactive approaches to maths, science and IT support for learning are being employed. Targeted resources are developed and sourced to meet the demand.

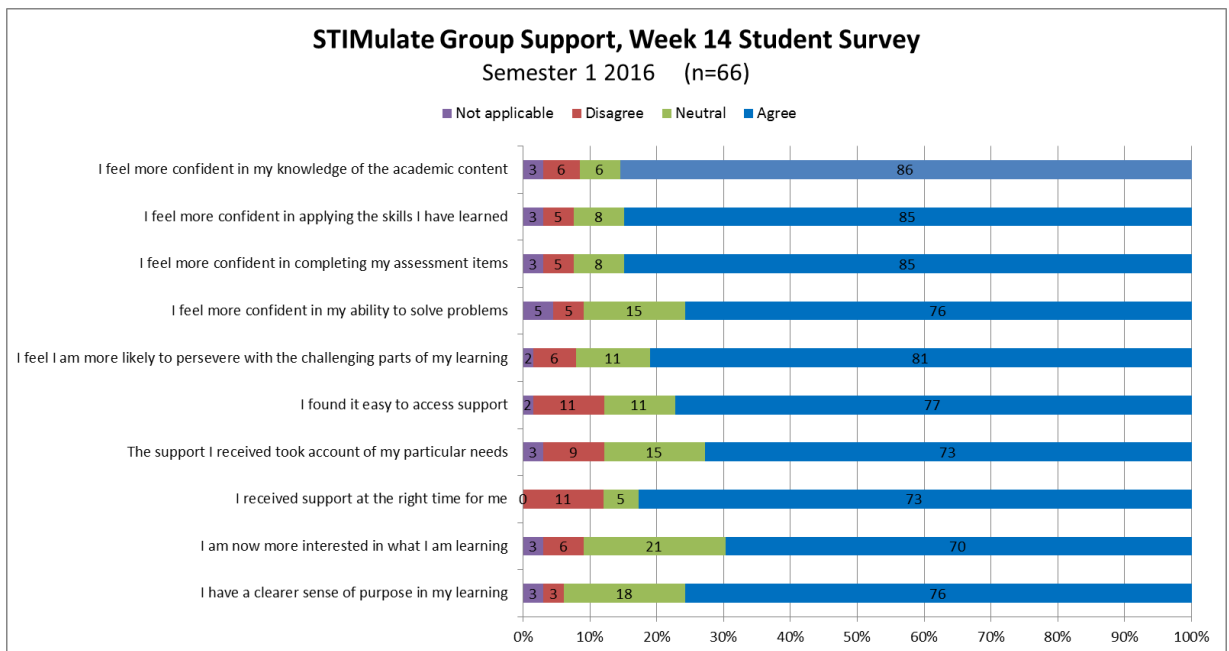
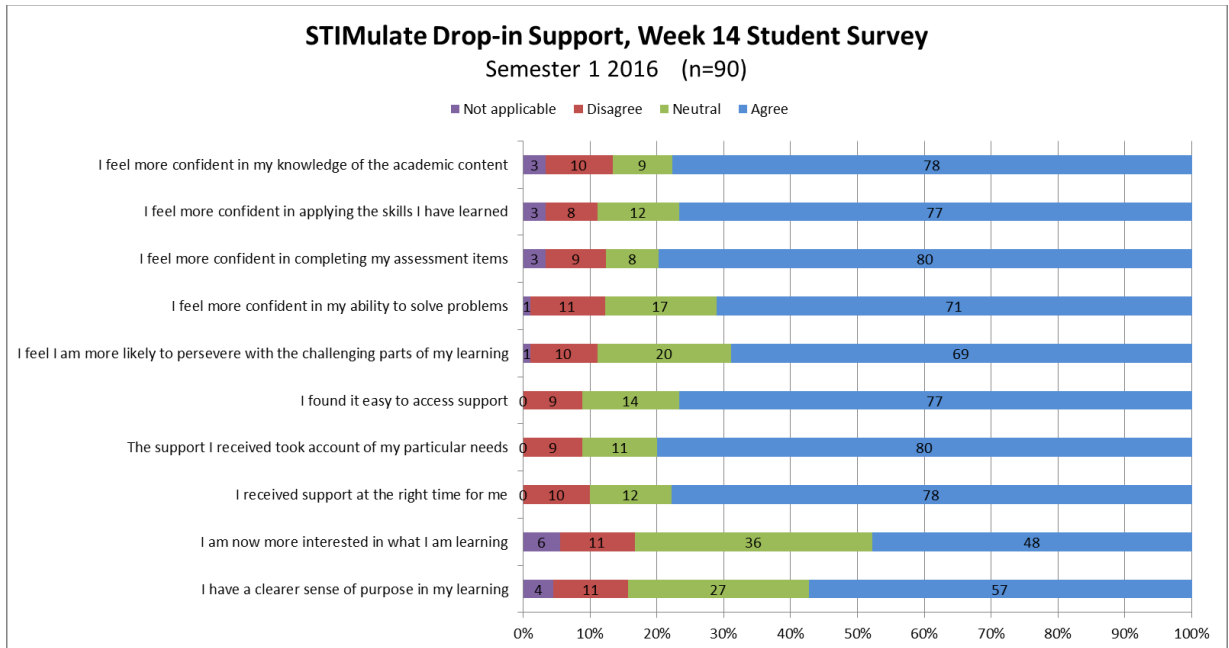
QUT's STIMulate program offers a model of how to optimally organise and deliver support for mathematics learning. It demonstrates how academics and students can effectively partner to deliver a quality service.

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# Appendix 1 ~ STIMulate Student Client Survey Feedback

In Semester 1 2016 a student survey was administered to all students who attended STIMulate. The results are summarized in the following graphs:



## Appendix 2 ~ STIMulate Program Statistics 2013-2016

| STIMulate program statistics      | 2013 | 2014 | 2015 | 2016 (to 27/7) |
|-----------------------------------|------|------|------|----------------|
| <b>Drop-in visits</b>             | 2500 | 2737 | 3163 | 1933           |
| <b>Group visits</b>               | 2233 | 2013 | 2928 | 1965           |
| <b>Group sessions</b>             | 282  | 268  | 404  | 252            |
| <b>Units supported</b>            | 169  | 237  | 235  | 151            |
| <b>Peer learning facilitators</b> | 80   | 117  | 141  | 143            |
| <b>PLF volunteer hours</b>        | 3200 | 3919 | 4806 | 2524           |
| <b>Academic FTE staff</b>         | 3    | 5.1  | 6.1  | 6.1            |
| <b>Professional FTE staff</b>     | 1    | 1    | 2    | 2              |