Papadopoulos, G. & Easdown, D. (2022). Student perspectives on summer school versus term-time for undergraduate mathematics. *International Journal of Innovation in Science and Mathematics Education, 30*(5), 39-58.

Supplementary Material

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Appendix 1: The 36 research questions

1.1. Overall I was satisfied with the quality of teaching by the teacher(s).
1.2. The work had been intellectually rewarding.
1.3. I developed relevant critical and analytical thinking skills.
1.4. I had good access to valuable learning resources.
1.5. The assessment tasks challenged me to learn.
1.6. I had been guided by helpful feedback on my learning.
1.7. Tutorials helped me to learn.
1.8. Staff were responsive to students.
1.9. Learning outcomes were clear to me.
1.10. The lecturers were effective in facilitating my learning.
1.11. The tutors were effective in facilitating my learning.
1.12. The unit of study materials were effective in facilitating my learning.
1.13. The exams were effective in testing my knowledge, understanding and aptitude.
1.14. The quizzes were effective in testing my knowledge, understanding and aptitude.
1.15. The assignments were effective in testing my knowledge, understanding and aptitude.
1.16. The homework was effective in testing my knowledge, understanding and aptitude.
1.17. The feedback in relation to assessment tasks was timely and of high quality.
1.18. I was personally motivated to pass or do well.
1.19. The pace was beneficial in facilitating my learning.
1.20. The timing was beneficial in facilitating my learning.
1.21. The lecture class sizes were appropriate for facilitating my learning.
1.22. The tutorial class sizes were appropriate for facilitating my learning.
1.23. I was able to focus on study without distraction.
1.24. Social context and interaction within/during scheduled classes were beneficial in facilitating my learning.
1.25. Social context and interaction outside/external to timetabled classes was beneficial in facilitating my learning.
2.1. Which mode of delivery did you find provided you with more enjoyment and satisfaction?
2.2. Which mode of delivery did you find provided you with better value for money, in terms of fees and your own resources?
2.3. Which mode of delivery did you find provided you with superior educational and learning outcomes?
2.4. Which mode of delivery did you find provided you with better compatibility with your own personal style of learning?
2.5. Which mode of delivery did you find provided you with units of study that were overall easier?
3.1. What were the reasons that you chose to enrol in mathematics units of study held during Summer School?
3.2. What were the best aspects of Summer School?
3.3. What were the best aspects of term-time?
3.4. What aspects of Summer School most need(ed) improvement?
3.5. What aspects of term-time most need(ed) improvement?
3.6. Do you have any additional comments that you would like to add to the Summer School versus term-time debate in general?

Questions 1.1-1.25 and 2.1-2.5 invite Likert responses with five possibilities for each question for both Summer School and term-time, as given in the following table. Numerical values were assigned in a standard way, for purposes of finding means, medians and *p*-values for the relevant statistical test:

Response		**Score**
Questions 1.1-1.25	**Questions 2.1-2.5**	
Strongly Disagree	Term-Time (by a large margin)	-2
Disagree	Term-Time (by a small margin)	-1
Neutral	Indifferent	0
Agree	Summer School (by a small margin)	1
Strongly Agree	Summer School (by a large margin)	2

The closed-ended questions (1.1-1.25 and 2.1-2.5) may be grouped as follows, corresponding to eleven subsections:

- Instruction (questions 1.1, 1.6, 1.8, 1.10, 1.11, 1.17)
- Learning (questions 1.3, 1.9, 1.23, 2.3, 2.4)
- Classes (questions 1.7, 1.21, 1.22)
- Motivation (question 1.18)
- Pace and Timing (questions 1.19, 1.20)
- Enjoyment (questions 1.2, 2.1)
- Resources (questions 1.4, 1.12)
- Assessment (questions 1.5, 1.13, 1.14, 1.15, 1.16)
- Easiness (question 2.5)
- Social (questions 1.24, 1.25)
- Value (question 2.2)

All questions invite open-ended comments.

Appendix 2: The seven categories (and their subcategories where appropriate) formed from the student statements, along with corresponding descriptions, key words and themes

Category	Sub-Categories	Description	Key Words and Themes
Structure	*Design* *Pacing* *Timing* *Fitment*	Students reflect upon the structure and design of the teaching and learning activities, assessment, materials and resources, and how conducive to and/or compatible these are with their own learning styles, preferences and capabilities. The pacing and timing of the delivery of the mathematics content, as well as the fitment (such as degree, course, or unit requirements) are influential factors in the students' learning.	Acceleration, adjacency, administration, alignment, arrangements, assessment, availability, block learning, breaks, clashes, completion, consolidation, constraints, continuation, convenience, coordination, cramming, credit points, delivery, demand, density, design, efficiency, enrolment, fitment, flexibility, flow, format, frequency, immediacy, integration, intensity, length, management, options, pacing, progression, repetition, requirements, revision, scheduling, spread, streams, structure, timing, variety, workload.
Learning Outcomes	*Quality* *Satisfaction*	The learning and understanding of mathematics content and underlying concepts are often evaluated against a personal measure of 'enjoyability' and sense of 'value'. Just how students feel challenged or motivated by their studies is dependent upon the balance of difficulty and quality of the content and assessment, as well as the learning environment. This in turn drives their level of satisfaction and the application of some combination of surface and deep learning strategies.	Alignment, appreciation, atmosphere, attendance, attention, authenticity, challenge, clarity, cohesion, comfort, commitment, communication, compatibility, completion, complexity, concentration, concepts, confidence, connection, consolidation, depth (of learning), development, difficulty, discussion, elaboration, encouragement, engagement, enjoyment, experience, exploration, familiarity, formality, formative vs. summative (assessment), independence, inspiration, intellect, intensity, interactivity, interest, knowledge, learning, motivation, outcomes, personal, practice, pressure, productivity, quality, reflection, relevance, retention, revelation, satisfaction, teaching, thinking, understanding, value.
Community	*Cohort Numbers* *Interactions*	There is considerable discussion as to how and why the number of students present in the teaching and learning activities influences their learning quality and experience. Regardless, it appears to be intricately shaped by their personal relationships and interactions with other students and staff, and an overall sense of 'community'.	Access (to resources), activity, camaraderie, campus, cohort, collaboration, commonality, communication, community, competition, cooperation, crowding, demand, discussion, disruption, encouragement, engagement, enrolment, environment, friendship, groups, inquiry, interactivity, intimacy, intimidation, liveliness, management, numbers (of students), opportunities, personal, rapport, socialising, support.
Instructors		The helpfulness and quality of the instruction by the teaching staff (lecturers, tutors, coordinators, etc.) is paramount in influencing student learning. Often students will either directly name or indirectly mention specific teaching staff, their methods, styles and characteristics, which have some significant impact upon their learning experiences.	Anecdotes, approachability, attentiveness, availability, charisma, clarity, effectiveness, effort, empathy, engagement, entertainment, enthusiasm, experience, explanations, feedback, formality, friendliness, guidance, helpfulness, influence, innovation, interactivity, interest, involvement, motivation, personality, position (of teacher), quality (of teaching), rapport, style, support, technology (use of), understandability.
Focus	*Motivation* *Task Management*	Student attitudes, in terms of their 'drive' or 'motivation' to study mathematics, are related to their ability to focus on their studies and varying levels of distraction. These depend upon personal circumstances, the management and balance of study, work and life tasks and goals.	Attendance, attention, attitude, balance, commitment, concentration, cramming, determination, discipline, distraction, focus, incentive, intensity, interest, isolation, laziness, motivation, multi-tasking, number (of tasks), pressure, quietness, responsibility, simplicity, simultaneity, stress, task management.
Affordability		'Value for money' is an important outcome of satisfaction for students; they express the desire to feel as if their learning outcomes are commensurate with the effort and financial costs involved. The affordability associated with undertaking particular mathematics units (of the students' choices) determine their ability to enrol and participate in delivery modes that suit their personal study needs.	Accessibility, affordability, choice, commitments, deferral, demand, deterrent, employment, expenses, fairness, fees, financing, free offer, funding, hinderance, hindsight, informedness, motivation, opportunity, outrage, payments, pressure, redo, responsibilities, satisfaction, subsidy, upfront, value-for-money.
Resources		The quality, availability and helpfulness of the teaching and learning resources (course notes, lecture slides, exercise sheets, etc.) are influential towards student learning.	Access, connection, consultation, demand, discussion board, exercises, external (resources), homework, infrastructure, legibility, LMS, MLC, notes, online, organisation, past papers, practice, quizzes, recordings, references, seating, slides, spaces, supplementary, technology, textbooks, venues, websites, worksheets.

Appendix 3: Techniques from phenomenography, the paradox of the Chinese Learner and modifications of the Presage-Product-Process (3P) model

Watkins and Biggs (1996, 2001b) had compiled studies, investigating a wide-spread phenomenon, in which students from countries with a Confucian Heritage Culture (CHC) were learning more effectively than Western research might have predicted in large class environments that emphasised memorisation and harsh socialisation practices. Our study similarly tries to understand the underlying dynamics of intensive learning environments, such as Summer School, that lead to unusually strong learning outcomes.

In the case of the Chinese paradox, plausible solutions were suggested within the context of Confucian cultures and their effects on cognitive abilities of learners (Watkins & Biggs, 1996, 2001a). That research employed a paradigm known as Student Approaches to Learning (SAL) (Biggs, 1987, 1993b; Entwistle & Ramsden, 1983), focusing on how students conceptualise learning. They used coding techniques from phenomenography, in the sense of Marton (1981) and Marton & Booth (1987), looking for qualitatively different categories, and connections between them, that underly how people experience or conceptualise phenomena.

In the spirit of SAL, we also focus on student perspectives and use techniques from phenomenography. For general references about coding, which allow categories to emerge from qualitative data, the reader is referred to Dewar *et al.* (2018), Ezzy (2002), Silverman (2014), Neumann (2011), Glaser & Strauss (1967), Bowden & Walsh (2000), Bowden & Green (2005) and Khan (2014).

The aim is to find similarities across perceptions of some given phenomenon (in our case, learning at Summer School and in term-time) expressed by some diverse group of individuals (in our case, students that took at least one unit at Summer School in the period 2009-2016). The focus is on collective characteristics of perceptions rather than individuals (Barnacle, 2005). Phenomenography derives its strength by looking at experience holistically, even though phenomena may be perceived differently by different people under different circumstances (Åkerlind, 2005). Groupings that emerge are called *categories of description* (or simply *categories*). Interviews are the main source of data in phenomenography, but open-ended responses in surveys are also common (Åkerlind & McKenzie, 2003; Åkerlind, 2005). After identifying categories, the task is to clarify and display relationships, using a table or network diagram (Dewar *et al.*, 2018). We used the dynamical systems approach of Biggs (1996b) to create a 3P diagram (Figure 32).

Phenomenography usually produces a relatively small number of categories. Watkins and Biggs (2001b) identified six main categories affecting learning quality in the context of the culture of the Chinese learner. Kember (1997) proposed five categories for studying conceptions of teaching in a Western context. Lingbiao and Watkins (2001) develop a model of conceptions using six categories, overlapping with Kember's, but overlayed with five categories that cut through "orthogonally", producing a cascade of dynamic models, with feedback loops. Dahlin *et al.* (2001) explored systemic relations between teachers and learners and the so-called "backwash effect" (see Biggs, 1995, 1996a; Hargreaves, 1997; Cheng, 1998; Prosser & Trigwell, 1999; Trigwell *et al.*, 1999). Their analysis used the constant comparative method of Glaser and Strauss (1967), by rereading scripts until categories emerged (see also Ng *et al.*, 2001, from a linguistic viewpoint). They identified six dimensions, with four dimensions "orthogonal" to two dimensions, culminating in dynamic relationships. Tang (2001), in studying the Chinese paradox, investigated relationships between conceptions of learning and teaching, producing six categories for each, and explored relationships between them. Biggs (1993a) sees the classroom as an ecosystem with interacting components. This may be part of a larger system, such as a school or institution, which embeds in even larger systems, such as the community and the broader culture. These systems produce complex multilayered equilibria, with "pedagogical flows" that may be characteristics of a particular mode of teaching and learning. Authors have investigated this as a cultural or geographical phenomenon (Schmidt, 1996; Stigler & Hiebert, 1999; Mok *et al.*, 2001; Biggs & Watkins, 2001), noticing relative uniformity within cultures, such as in Japan, the United States, Germany and CHC countries, compared with vast differences between cultures. Biggs and Watkins (2001) observe that Japanese schools have a mechanism, *kounaikenshuu,* for enhancing the quality of learning, involving observation, analysis and refinement, and that similar reflective mechanisms exist in Chinese schools. They explain the Chinese paradox by noting that, in the West, focus on presage factors tends to be in isolation rather than as part of an integrated cultural system. They refer to three levels: at the lowest level, teaching is exposition and differences in learning outcomes are dependent on personal attributes of the student. At the next level, teachers think about presentation skills, with emphasis on their performance, disregarding whether this results in improved learning. At the highest level, teachers encourage students to engage in appropriate activities, where all aspects of the teaching/learning context interact, including design, delivery and assessment, creating an integrated system. We investigate, in our study, distinctive features of Summer School, sharing certain aspects with term-time, that possibly lead to a vibrant culture of learning, operating at this highest level.

Biggs (1996b), in studying the Chinese paradox, modifies his 3P model. The cultural context for CHC students is of fundamental importance and is incorporated in his "culturally modified" 3P model (Figure 33). Salili (2001) also argues that culture has a profound impact on motivation to learn and students' interactions, creating reciprocal effects and feedback loops (see also Pintrich & Schunk, 1996). Cortazzi & Lixian (2001) model interactions in large classes in China, on the premise that learning is fundamentally cultural. Their model, however, is teacher focused, with ideological background and culture as the starting point, and quality learning outcomes as the finishing point, with scope for dynamic interaction.

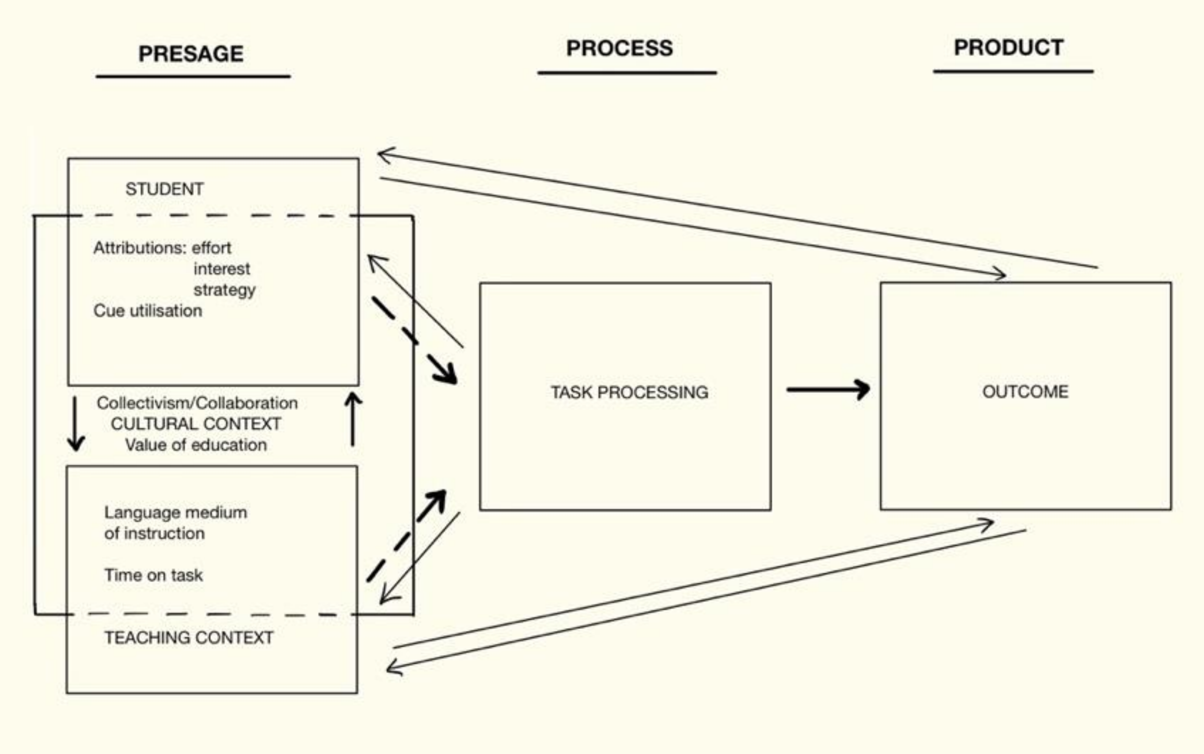

Figure 33. The Biggs' "culturally modified" 3P Model in the CHC context.

Appendix 4: Background and context for mathematics units of study at The University of Sydney Summer School

The IMD (Summer School) program at The University of Sydney, in the period 2009-2016, spanned six weeks in January and February. The two regular semesters each spanned 13 weeks. Each semester contained two study breaks, one mid-semester, and one between the end of lectures and examinations. Relatively long breaks did not feature in Summer School. Nine mathematics units of study were offered at Summer School, practically identical to their term-time counterparts, with at most minor changes to facilitate and optimise scheduling. These units were categorised as follows:

- ***Fundamental*** (two first year) – designed for students who do not intend to take mathematics beyond first year, featuring applications in biological and social sciences.
- ***Mainstream*** (five first year and two second year) – designed for students who intend to take mathematics beyond first year (including engineering and mathematics majors), featuring physical sciences applications as well as abstract or pure mathematics.

It is worth noting that *Advanced* units were not available at Summer School. Advanced units are typically taken by talented students, contemplating pathways towards Honours or postgraduate research degrees. Though there was nothing to prevent them from enrolling in Summer School, such high achieving students were not represented in this study.

In what follows, we denote the units taught at Summer School as F1a and F1b (Fundamental first year); M1b, M1c, M1d, M1e (Mainstream first year) and M2a and M2b (Mainstream second year). The paragraphs have been taken verbatim (aside from the pseudonyms given to the unit of study names) from the University of Science Faculty of Science Handbook 2015.

***[F1a]** is designed for science students who do not intend to undertake higher year mathematics and statistics. It establishes and reinforces the fundamentals of calculus, illustrated where possible with context and applications. Specifically, it demonstrates the use of (differential) calculus in solving optimisation problems and of (integral) calculus in measuring how a system accumulates over time. Topics studied include the fitting of data to various functions, the interpretation and manipulation of periodic functions and the evaluation of commonly occurring summations. Differential calculus is extended to functions of two variables and integration techniques include integration by substitution and the evaluation of integrals of infinite type.*

***[F1b]** is designed for science students who do not intend to undertake higher year mathematics and statistics. In this unit of study students learn how to construct, interpret and solve simple differential equations and recurrence relations. Specific techniques include separation of variables, partial fractions and first and second order linear equations with constant coefficients. Students are also shown how to iteratively improve approximate numerical solutions to equations.*

***[M1a]** is designed to provide a thorough preparation for further study in mathematics and statistics. It is a core unit of study providing three of the twelve credit points required by the*

Faculty of Science as well as a Junior level requirement in the Faculty of Engineering. This unit of study looks at complex numbers, functions of a single variable, limits and continuity, vector functions and functions of two variables. Differential calculus is extended to functions of two variables. Taylor's theorem as a higher order mean value theorem.

***[M1b]** is designed to provide a thorough preparation for further study in mathematics and statistics. It is a core unit of study providing three of the twelve credit points required by the Faculty of Science as well as a Junior level requirement in the Faculty of Engineering. This unit of study introduces vectors and vector algebra, linear algebra including solutions of linear systems, matrices, determinants, eigenvalues and eigenvectors.*

***[M1c]** is designed to provide a thorough preparation for further study in mathematics and statistics. It is a core unit of study providing three of the twelve credit points required by the Faculty of Science as well as a Junior level requirement in the Faculty of Engineering. This unit of study first develops the idea of the definite integral from Riemann sums, leading to the Fundamental Theorem of Calculus. Various techniques of integration are considered, such as integration by parts. The second part is an introduction to the use of first and second order differential equations to model a variety of scientific phenomena.*

***[M1d]** is designed to provide a thorough preparation for further study in Mathematics. It is a core unit of study providing three of the twelve credit points required by the Faculty of Science. This unit provides an introduction to fundamental aspects of discrete mathematics, which deals with 'things that come in chunks that can be counted'. It focuses on the numeration of a set of numbers, viz. Catalan numbers. Topics include sets and functions, counting principles, Boolean expressions, mathematical induction, generating functions and linear recurrence relations, graphs and trees.*

***[M1e]** is designed to provide a thorough preparation for further study in mathematics and statistics. It is a core unit of study providing three of the twelve credit points required by the Faculty of Science as well as a Junior level requirement in the Faculty of Engineering. This unit offers a comprehensive introduction to data analysis, probability, sampling, and inference including t-tests, confidence intervals and chi-squared goodness of fit tests.*

***[M2a]** starts with an investigation of linearity: linear functions, general principles relating to the solution sets of homogeneous and inhomogeneous linear equations (including differential equations), linear independence and the dimension of a linear space. The study of eigenvalues and eigenvectors, begun in junior level linear algebra, is extended and developed. The unit then moves on to topics from vector calculus, including vector-valued functions (parametrised curves and surfaces; vector fields; div, grad and curl; gradient fields and potential functions), line integrals (arc length; work; path-independent integrals and conservative fields; flux across a curve), iterated integrals (double and triple integrals; polar, cylindrical and spherical coordinates; areas, volumes and mass; Green's Theorem), flux integrals (flow through a surface; flux integrals through a surface defined by a function of two variables, though cylinders, spheres and parametrised surfaces), Gauss' Divergence Theorem and Stokes' Theorem.*

***[M2b]** is an introductory course in the analytical solutions of PDEs (partial differential equations) and boundary value problems. The techniques covered include separation of variables, Fourier series, Fourier transforms and Laplace transforms.*

Appendix 5: Representative student comments that accompany histograms

For **Instruction** (Figures 2-7):

> *Teachers in [Summer School] were more likely to engage with us on an individual and personal basis, remembering the mistakes made in previous weeks, having a good idea of individual student level.*

For **Learning** (Figures 8-12):

> *When you have more time (as it was during Summer School) you get to engage [with] content and learn and appreciate it more, and therefore I think I thought about assessments critically and analytically rather than being robotic about it like during term-time.*

For **Classes** (Figures 13-15):

> *Term-time classes were too large.*

> *The Summer School lectures felt a lot more like tutorials.*

For **Motivation** (Figure 16):

> *The motivation is stronger for Summer School because you become much more involved in learning, so it becomes natural to be motivated.*

> *I just wanted to get my degree done as fast as possible, so I took two subjects at Summer School.*

For **Pace and Timing** (Figures 17-18):

> *The fast pacing of Summer School meant it was easier to recall and revise concepts from the beginning of the course when studying for exams. However, the fast pacing also made it difficult to keep on top of all the content and stay organised.*

> *It's hard to have timing effective in Summer School because many people are only attending one subject and may be travelling [from] far away. I personally found it overwhelming covering two weeks' worth in normal term[-time] in two days during Summer School …*

For **Enjoyment** (Figures 19-20):

> *The help of focusing on one unit in Summer School allowed me to both concentrate and find enjoyment in solving the problems, as opposed to term-time where you have less time to appreciate the work.*

For **Resources** (Figures 21-22):

> *Summer School extra practice questions were the real differentiator.*

> *The Mathematics Learning Centre was a valuable resource during term-time. Would have been good to have access to during Summer School.*

For **Assessment** (Figures 23-27):

> *Summer School assessment tasks felt more challenging.*

> *Term-time assessment tasks weren't that different from Summer School.*

For **Easiness** (Figure 28):

> *… it was easier in Summer School with the smaller class, lecturer and tutor being the same person and them having a lot of time to help each student …*

> *They felt easier in term-time – again because all the content wasn't as rushed.*

For **Social** (Figures 29-30):

> *It's easier to learn from peers during term-time because people hang around more.*

> *During term-time I felt like the stupid one in the class whereas in Summer School most of the people in the class were in a similar position to me, which meant I felt more comfortable asking questions and discussing the content with my peers.*

For **Value** (Figure 31):

> *If Summer School cost the same as the regular courses in [term-time], I would say Summer School is better value …*