Who is tasked with modernisation of mathematics education? Research mathematicians and mathematics education researchers bridging the disciplinary gap

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

SCIENCE

Tanya Evans
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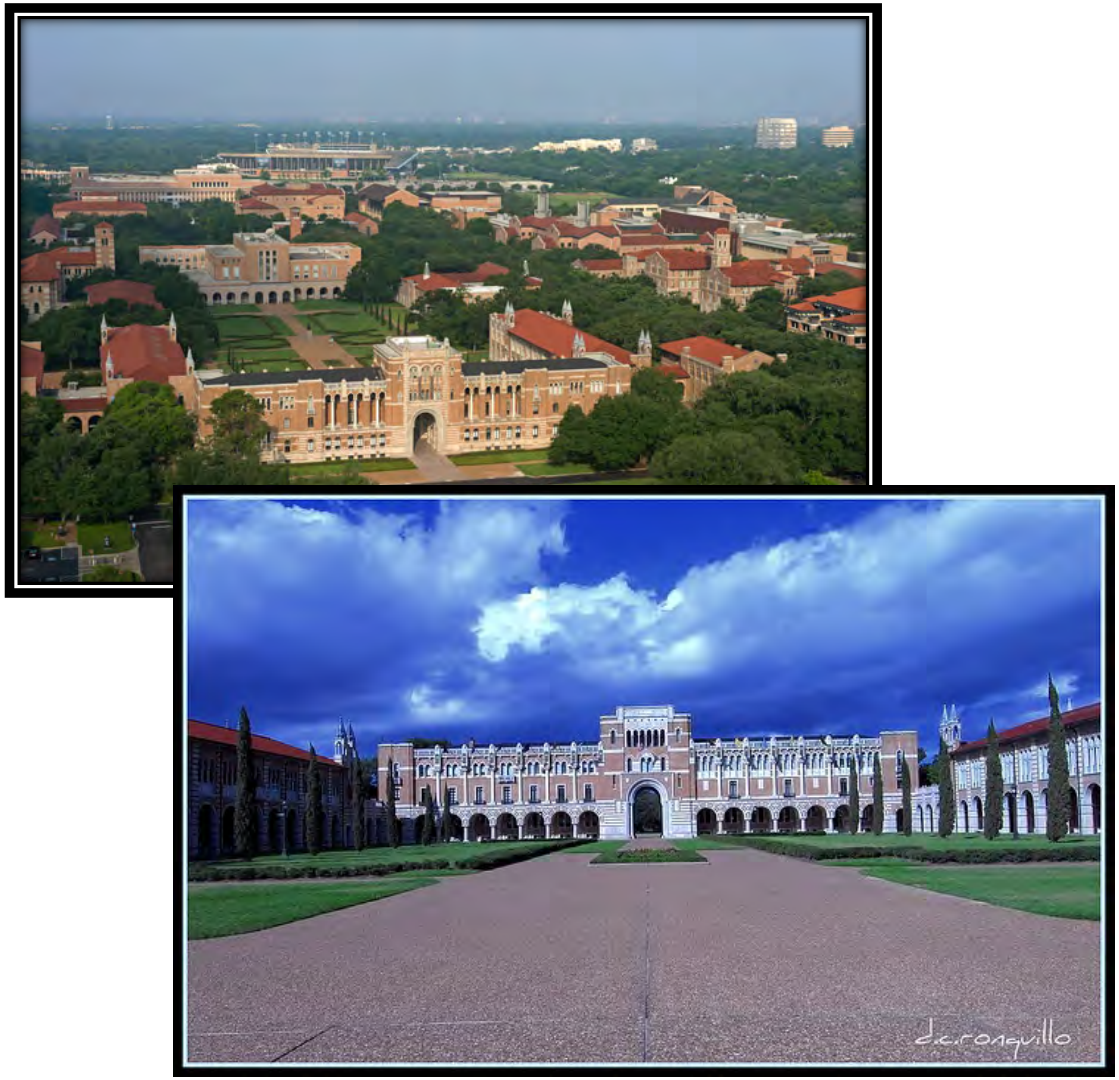
Twitter @DrTanyaEvansNZ

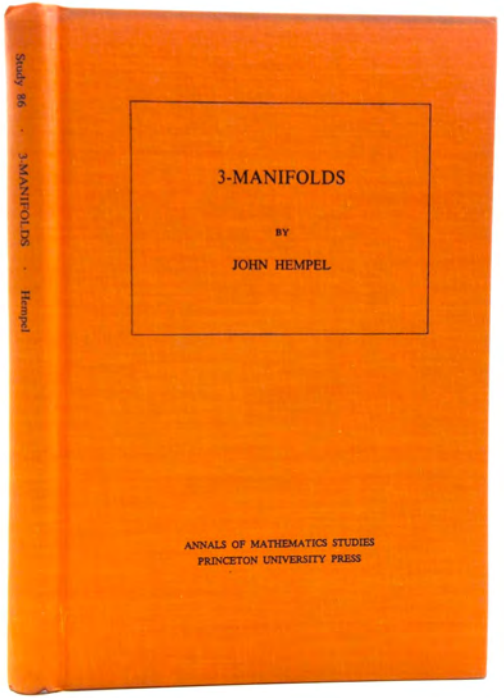
From Russia with love… for mathematics

St Petersburg → Rice University, Houston, Texas

Rice University – PhD in Maths



Prof. John Hempel



Evans, T. (2006). High distance Heegaard splittings of 3-manifolds. *Topology and its Applications, 153*(14), 2631-2647.

Teaching experience

- Stage I maths for majors and non-majors – (2002-…)
- Topology, Real Analysis, Complex Analysis, Measure Theory - Massey University (2005-2011)
- Stage II maths for non-majors – UoA (2012-…)
- Financial Mathematics (stage III and postgrad level) – UoA (2014-…)

Reflections of change:

Globally, the higher education sector is challenged to keep up with the times and reassess its sustainability in a technological era.

Change in research interests: joined the Mathematics Education Unit (within the Department of Mathematics, UoA)

Systemic issue in university mathematics education

- lack of research-informed evidence-based approaches to teaching and learning
- the core driver is the disciplinary disconnect: most research mathematicians do not research in mathematics education

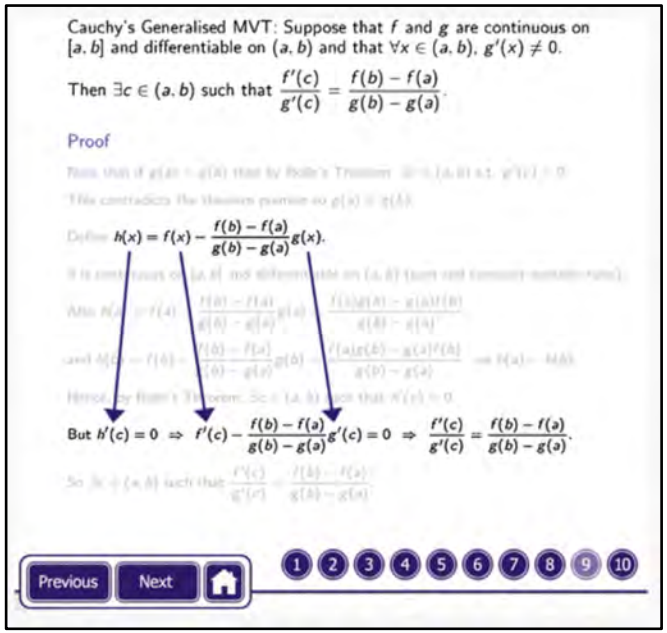
- academic inertia: traditional transmitting style of teaching
- or experimentation with new modes of delivery by enthusiastic innovators without conducting rigorous research

- innovations are often based on integration of new technological gadgets for use in mathematics education with only anecdotal evidence about their merits

Cautionary tale

Roy, S. Inglis, M. & Alcock, L. (2017). Multimedia resources designed to support learning from written proofs: an eye-movement study. *Educational Studies in Mathematics, 96*, 249-266.

E-Proof: multimedia recourse that presented proofs with audio commentary and visual animations to focus attention on logical relationships.



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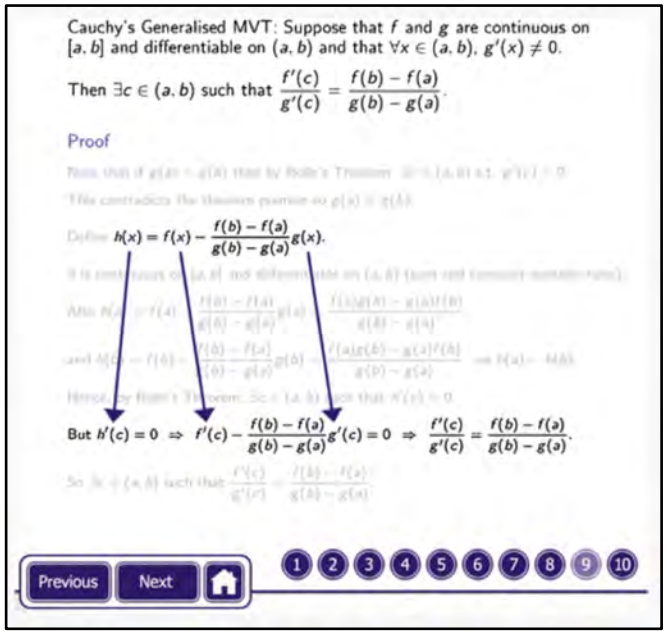

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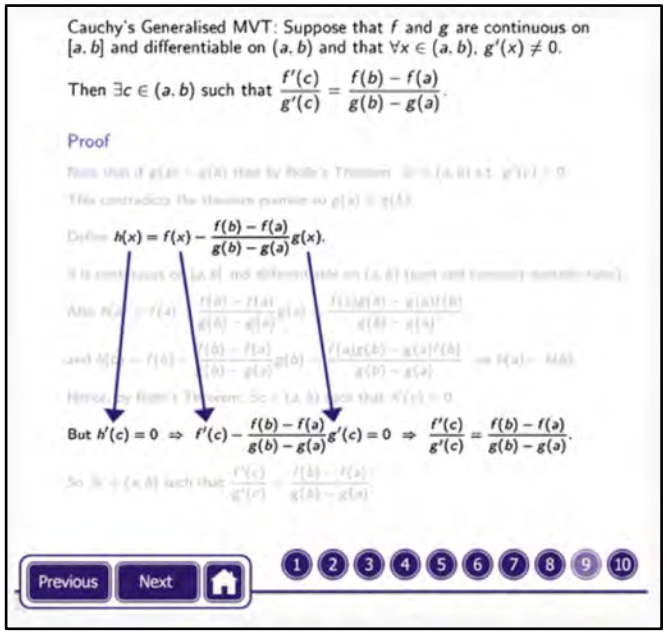

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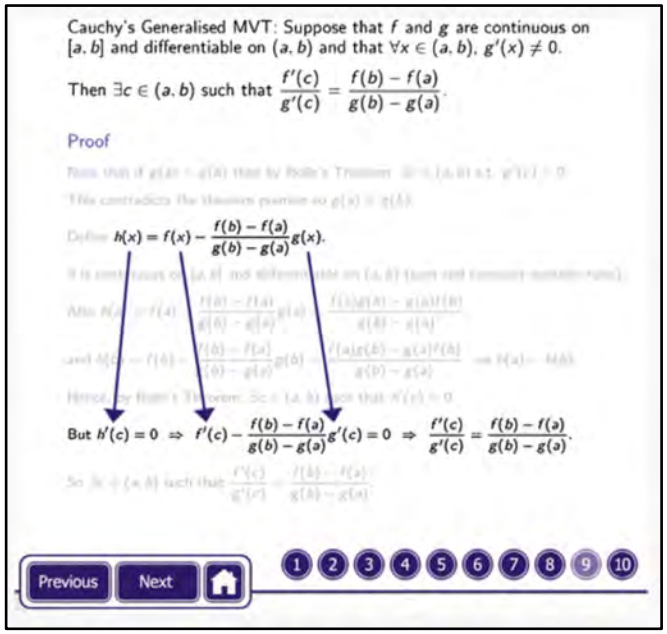

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Extra support offered by e-Proofs disrupts the processes by which students organise information, and thus impair the process of integration of new understanding with existing knowledge.
Implications: Who is responsible for evaluation of new interventions?

Proposal for the field: bridge the disciplinary gap

by focusing on the following research themes:

Theme 1: Developing frameworks for conducting evaluation research in a realistic university setting for testing an innovation that aims to integrate insights from broader educational research.

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Our study:

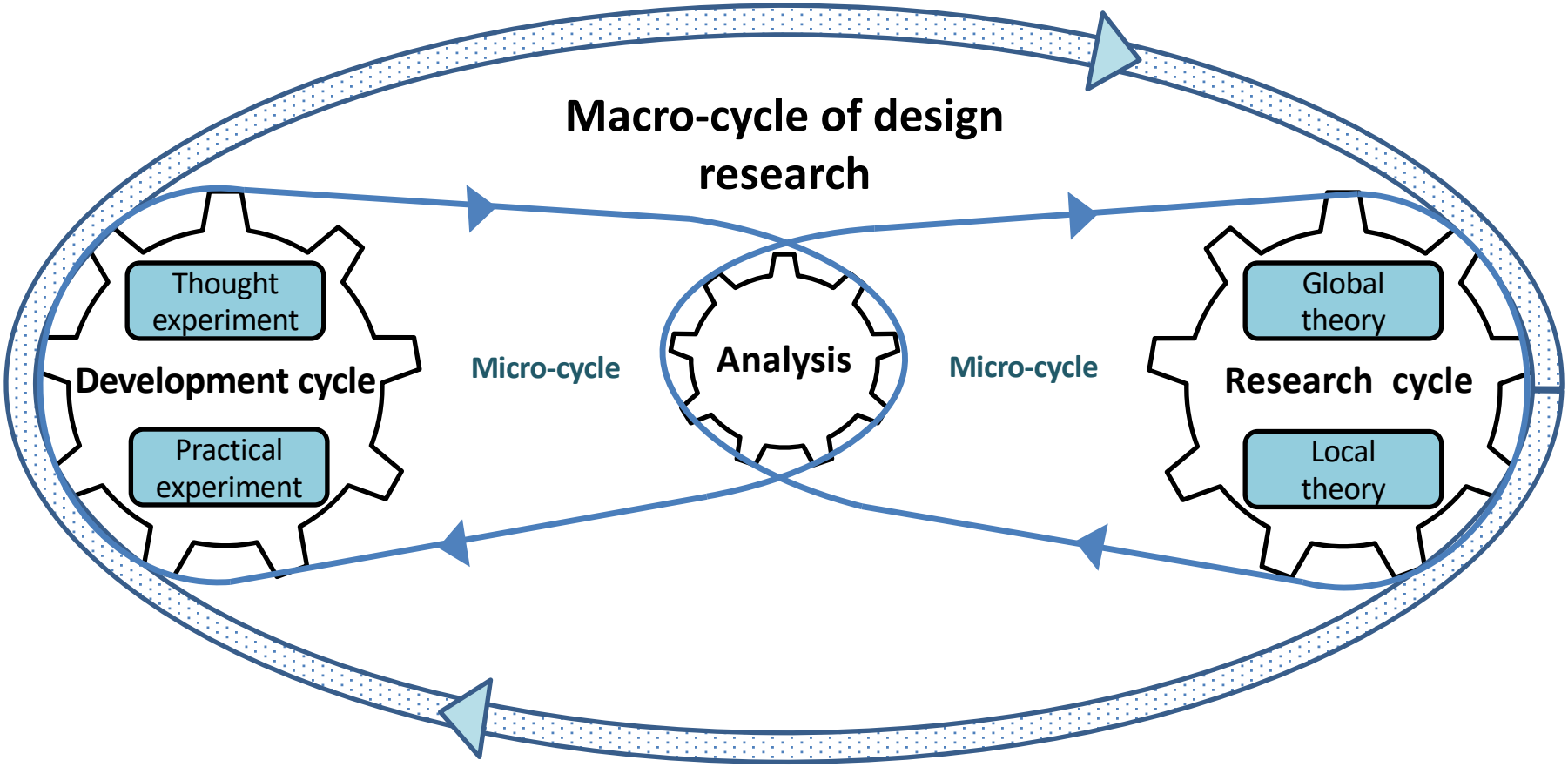
- evaluation research in a realistic university setting
- testing an innovation
- integrating insights from experimental cognitive psychology

Dr. Barbara Kensington-Miller

Dr. Julia Novak

Evans, T., Kensington-Miller, B., & Novak, J. (2019). Exploring the impact of pre-lecture quizzes in a university mathematics course. In M. Graven, H. Venkat, A. Essien & P. Vale (Eds.). *Proceedings of the 43rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 232-239). Pretoria, South Africa: PME.

Methodology: design research



Design research: cogwheels in motion, chain-driven by design principles (adapted from Goodchild, 2014).

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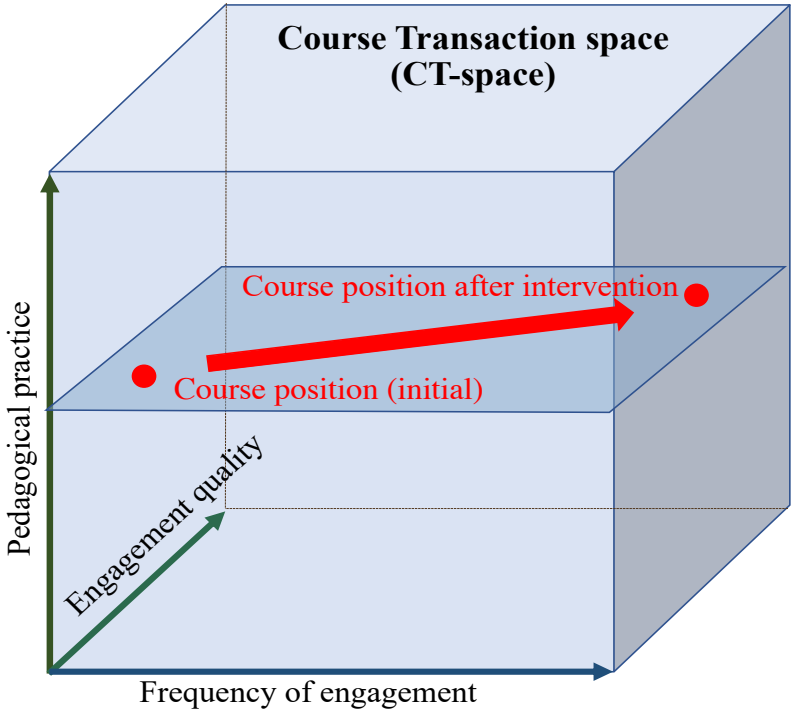
y-axis	• Quality of learners' engagement
z-axis	• Pedagogical practice



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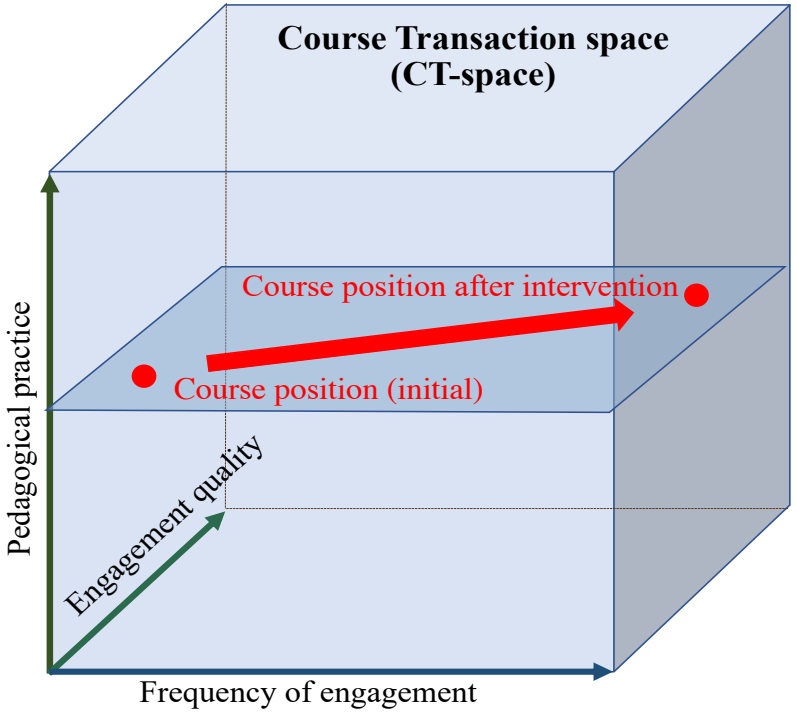

Framework utility: in isolating factors and in capturing relative changes along the axes.

The effectiveness and efficiency of educational exchange is affected not only by the distance from the origin, but also by the position of the course in the *CT-space:* mathematics courses can be represented as a sequence of points in the *CT-space.*

Intervention: design principles

Integrating insights from experimental cognitive psychology: the effect of distributed (spaced) practice – an effect of interstudy interval (ISI) upon learning (measured by test performance):

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- Best 28 (out of 32) scores counted towards 7% of the final grade
- Each quiz contains 2 questions assessing the material from the previous lecture

Quiz:

If each quiz is worth 0.25% of the final grade, what percentage of students completed all 28 quizzes required?

A) less than 10%

B) 10-30%

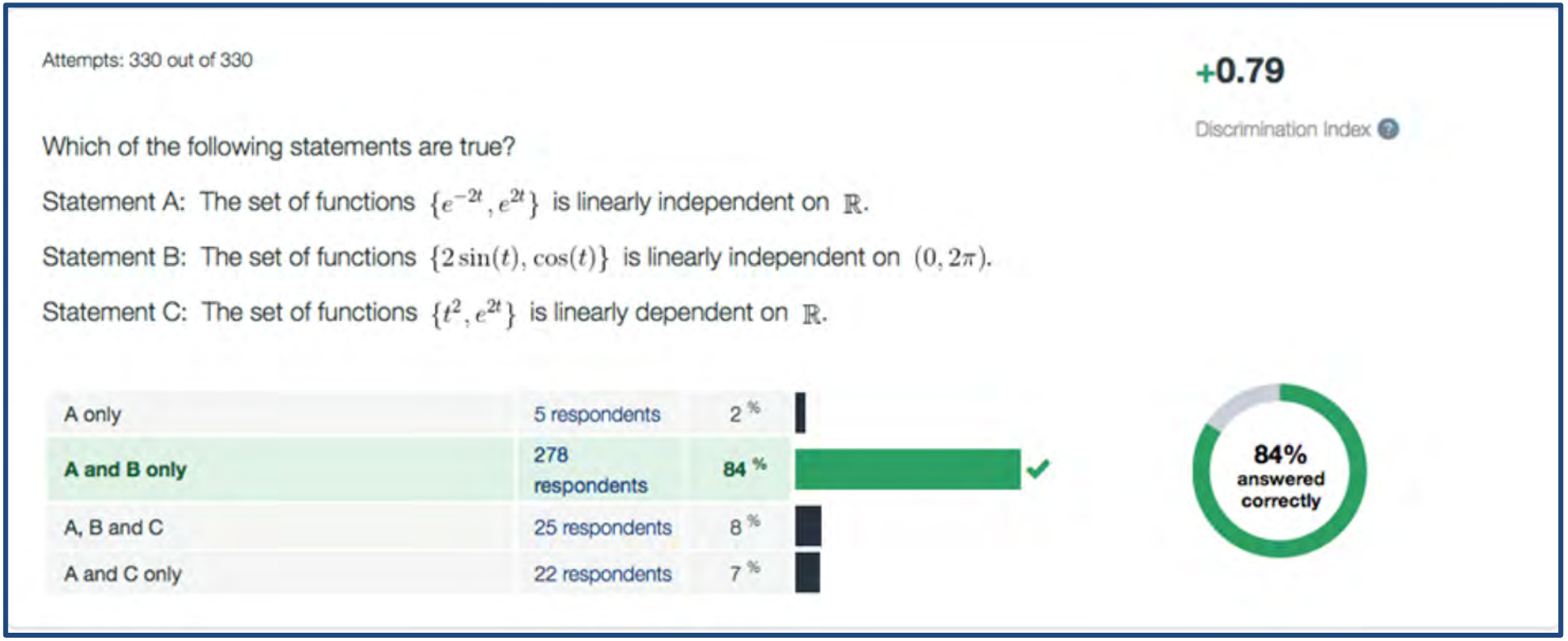
C) 31-50%

D) 51-70%

E) 71-90%

F) more than 90%

Example: Canvas quiz analytics



Attempts: 330 out of 330

+0.79

Discrimination Index

Which of the following statements are true?

Statement A: The set of functions $\{e^{-2t}, e^{2t}\}$ is linearly independent on $\mathbb{R}$.

Statement B: The set of functions $\{2\sin(t), \cos(t)\}$ is linearly independent on $(0, 2\pi)$.

Statement C: The set of functions $\{t^2, e^{2t}\}$ is linearly dependent on $\mathbb{R}$.

A only	5 respondents	2 %
A and B only	278 respondents	84 %
A, B and C	25 respondents	8 %
A and C only	22 respondents	7 %

84% answered correctly

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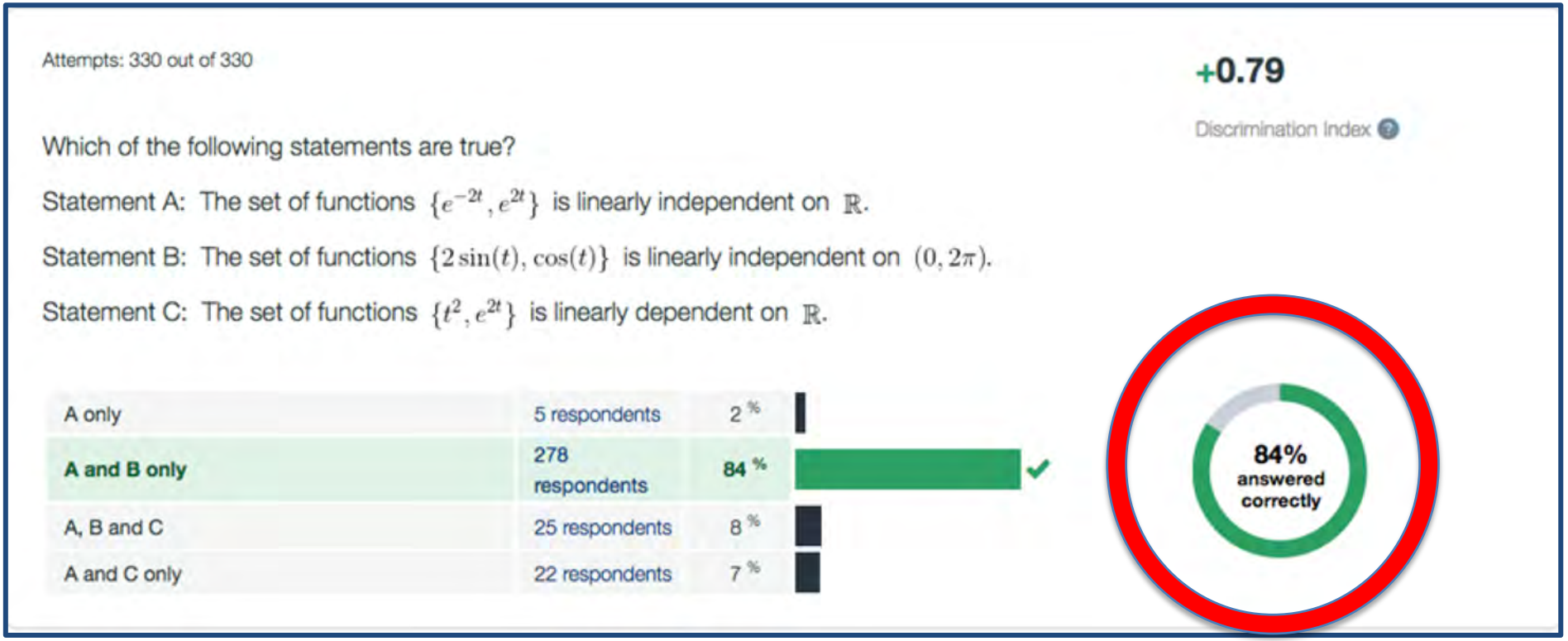

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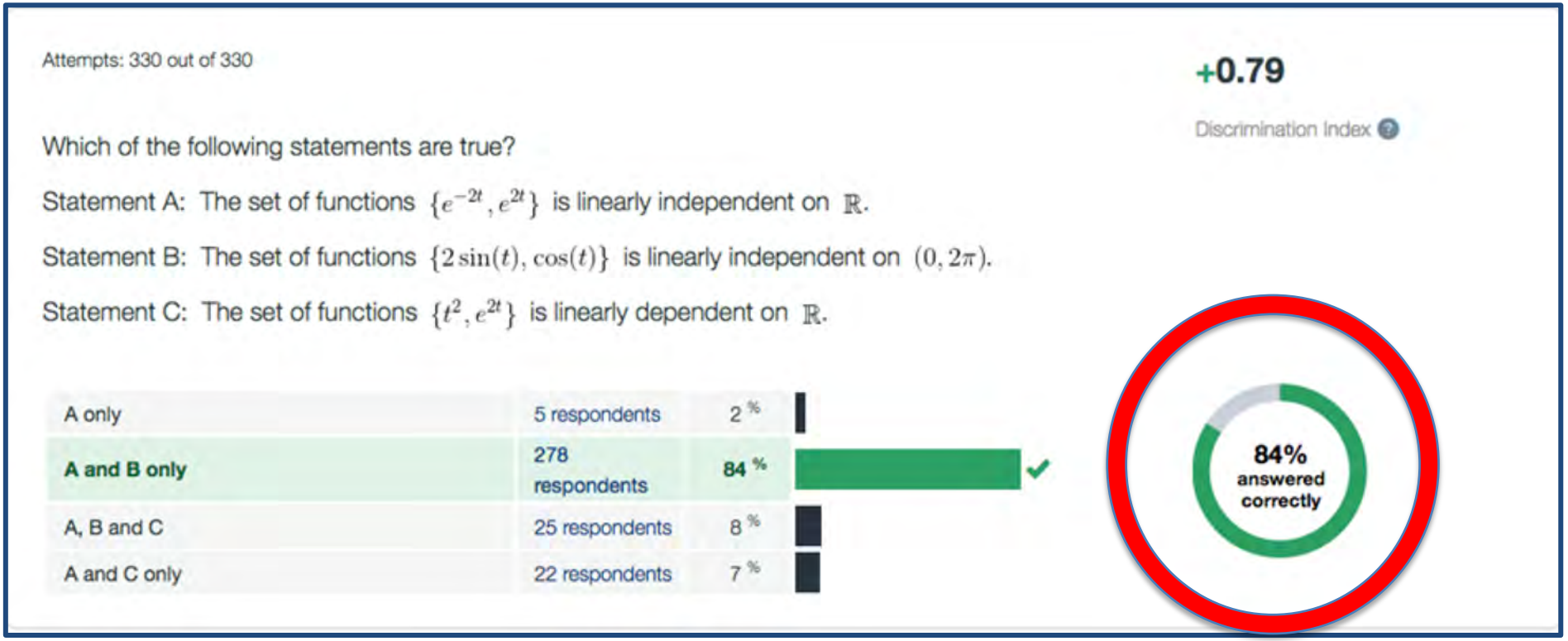
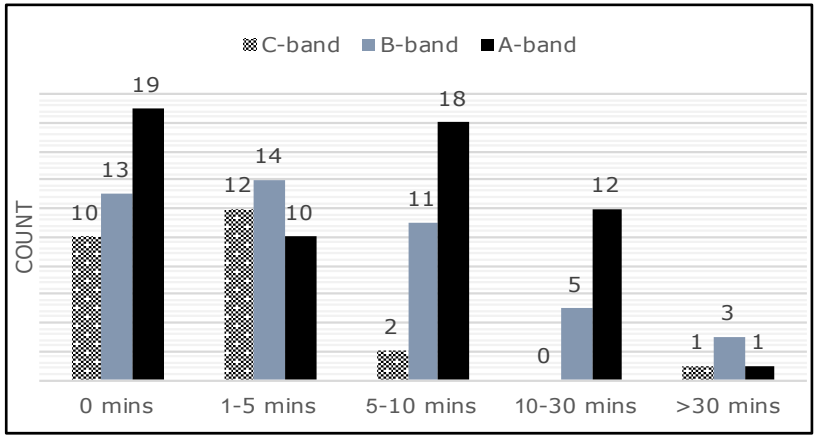


The large majority of students successfully completed the quizzes with the mean score of 90.76% (*SD*=13.04%) – two attempts were given with 30 min time limit for each attempt.

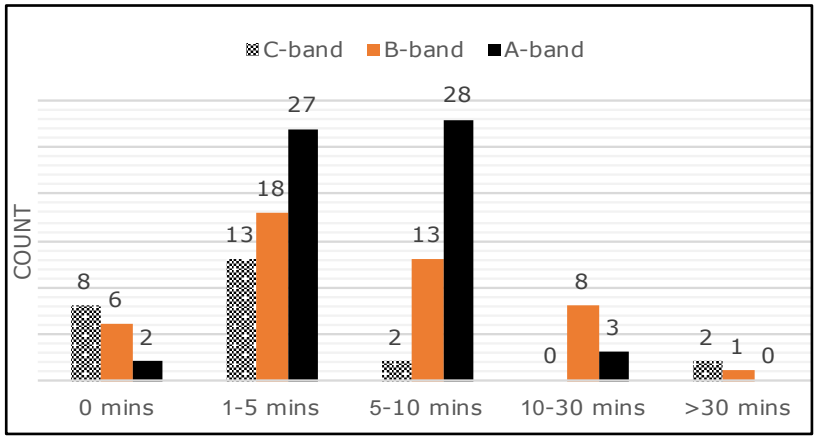
Survey

- Questionnaire: paper-based, conducted in class at the end of the semester, response rate: 98% of students who were present with 140 individual responses.
- What do students do when preparing to take a quiz?
- And, more importantly, if their first attempt is incorrect (the online system automatically provides instant feedback alerting the student), would they take the time to refer to their notes and other resources?

Time spend studying before first attempt at quizzes



Time spend studying before second attempt at quizzes



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- And, more importantly, if their first attempt is incorrect (the online system automatically provides instant feedback alerting the student), would they take the time to refer to their notes and other resources?
- Over 68% of students reported that they spend time studying before taking the first attempt. Moreover, significantly more students (88%) responded that they will spend time studying before the second attempt ($\chi^2(2)=18.89$, $p=<.001$), Cramér's $V=0.87$; z-test for proportion, $z=-2.53$, $p=.012$).

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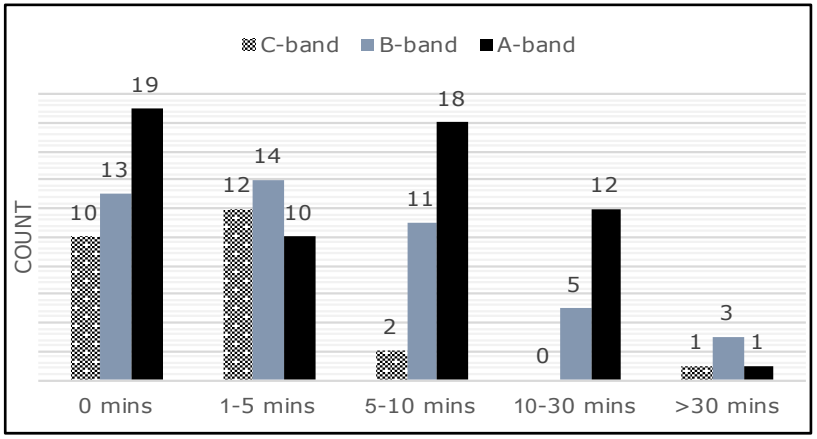

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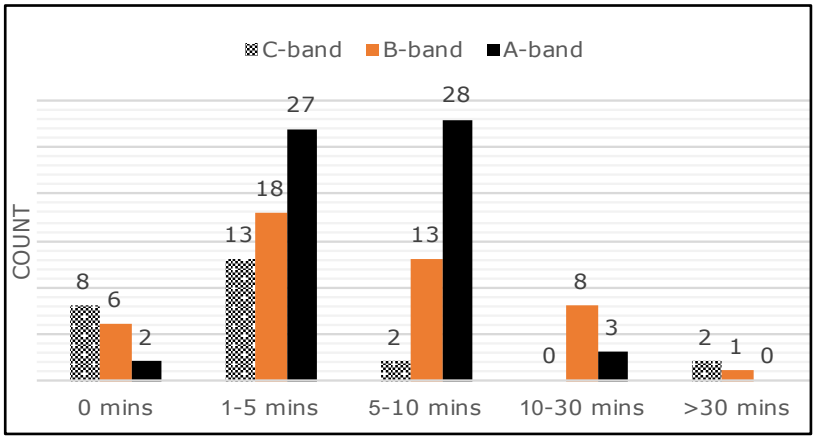
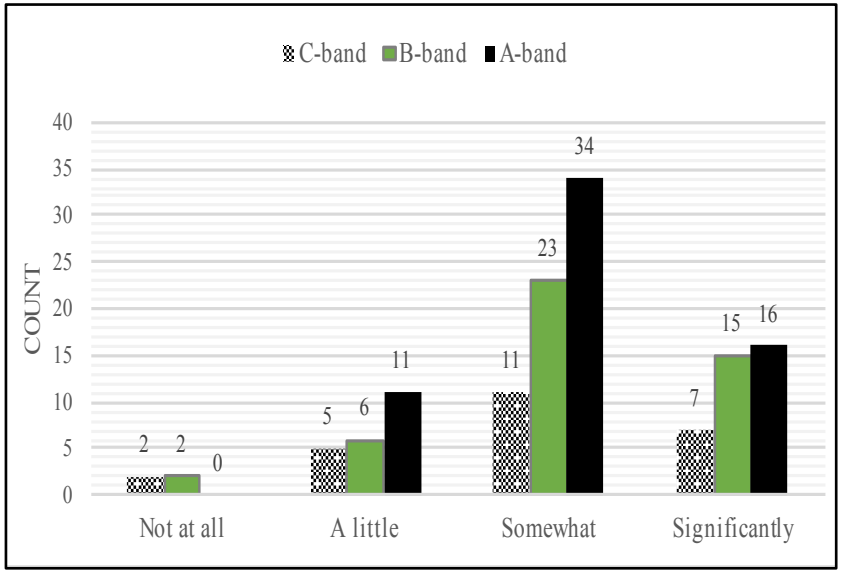


Competence-related beliefs

Contribution of quizzes to understanding of material by grade band



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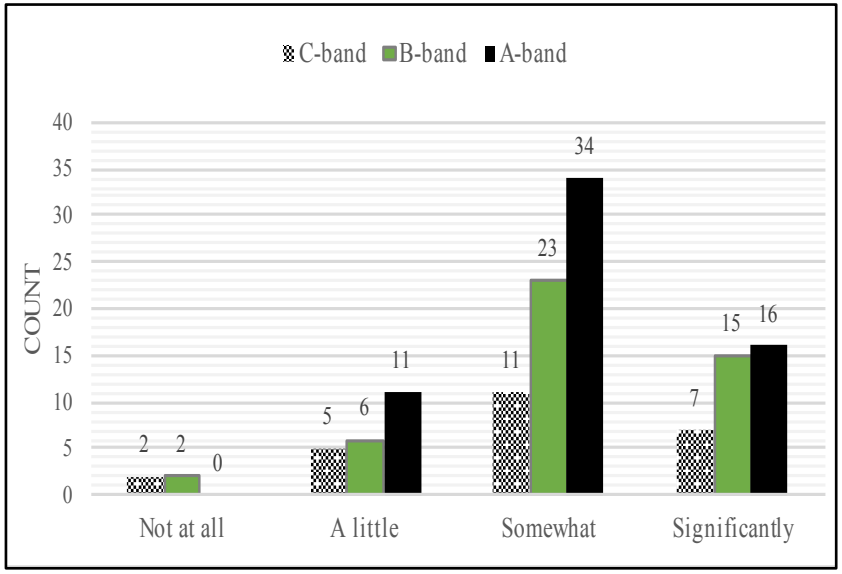

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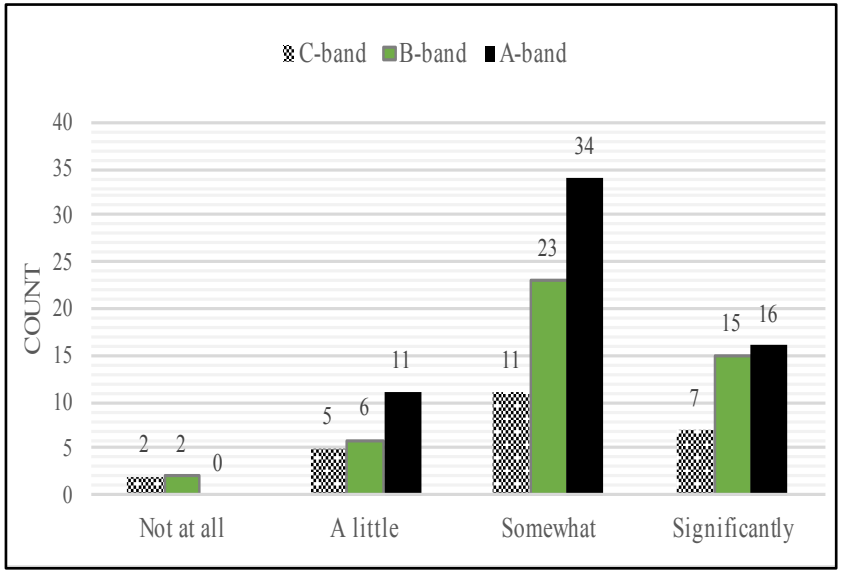

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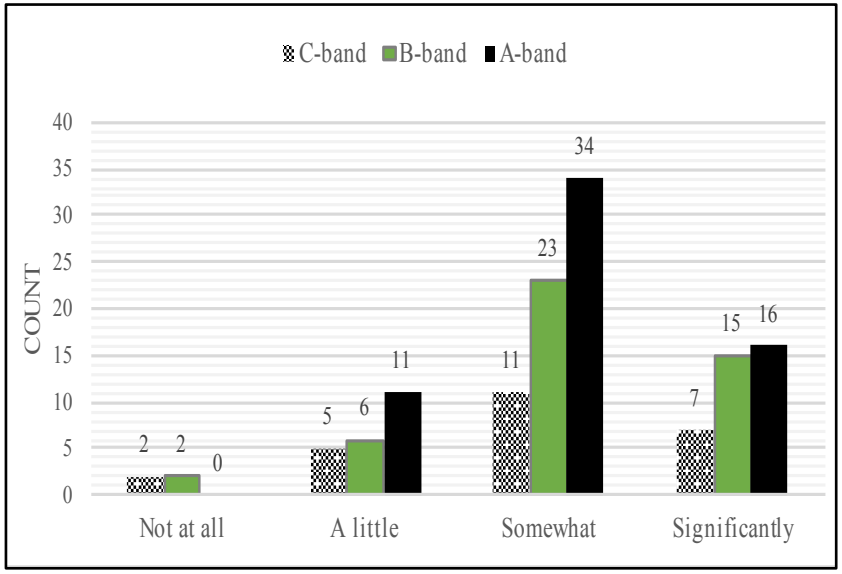

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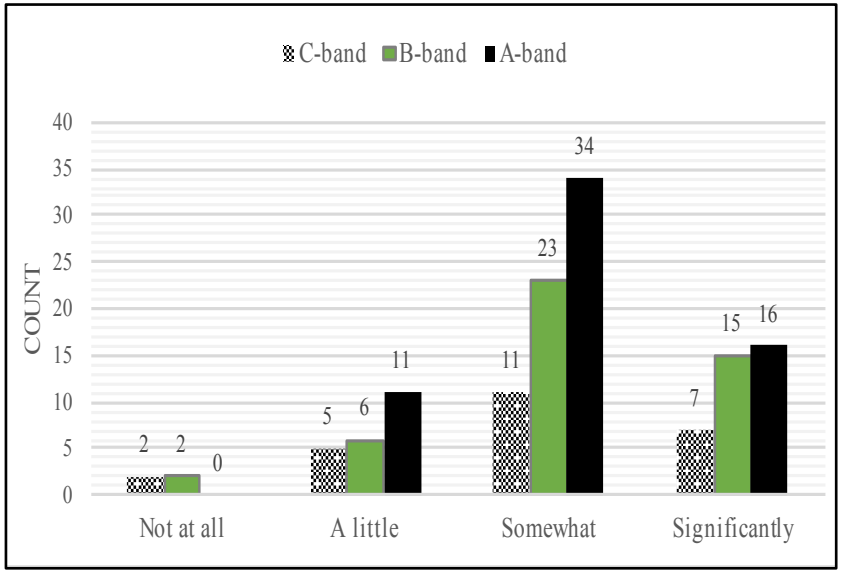

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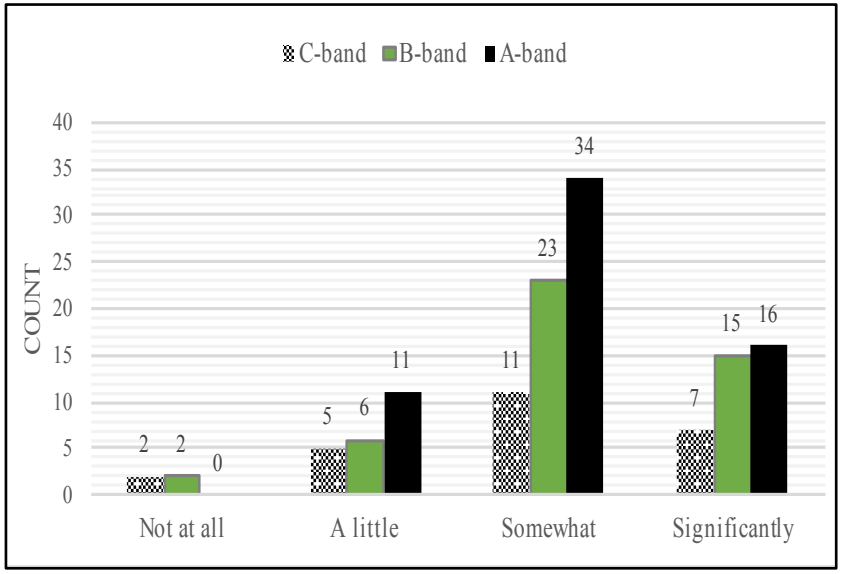

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In our study: we introduced new tasks (online quizzes) - the majority of students perceived these tasks as value-adding (contributing to their understanding). Thus, it is plausible to suggest that the introduction of quizzes enabled higher level of academic engagement.

Self-efficacy through mastery experience

- Self-efficacy is a powerful predictor for students' achievement and learning outcomes as believing that one has a capacity to perform promotes academic engagement (Middleton, Jansen, & Goldin, 2016; Pantziara, 2016; Schukajlow, Achmetli & Rakoczy, 2019; Skaalvik, Federici, & Klassen, 2015).

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- Plausible: the introduction of quizzes made an impact on amplifying students' mastery experiences (students performed significantly better on the quizzes than on the written assignments with a mean increase of 12.72% on their scores, 95% CI [10.71, 14.74], paired-samples t-test: $t(388)=12.4$, $p<.0001$, $d=0.63$).

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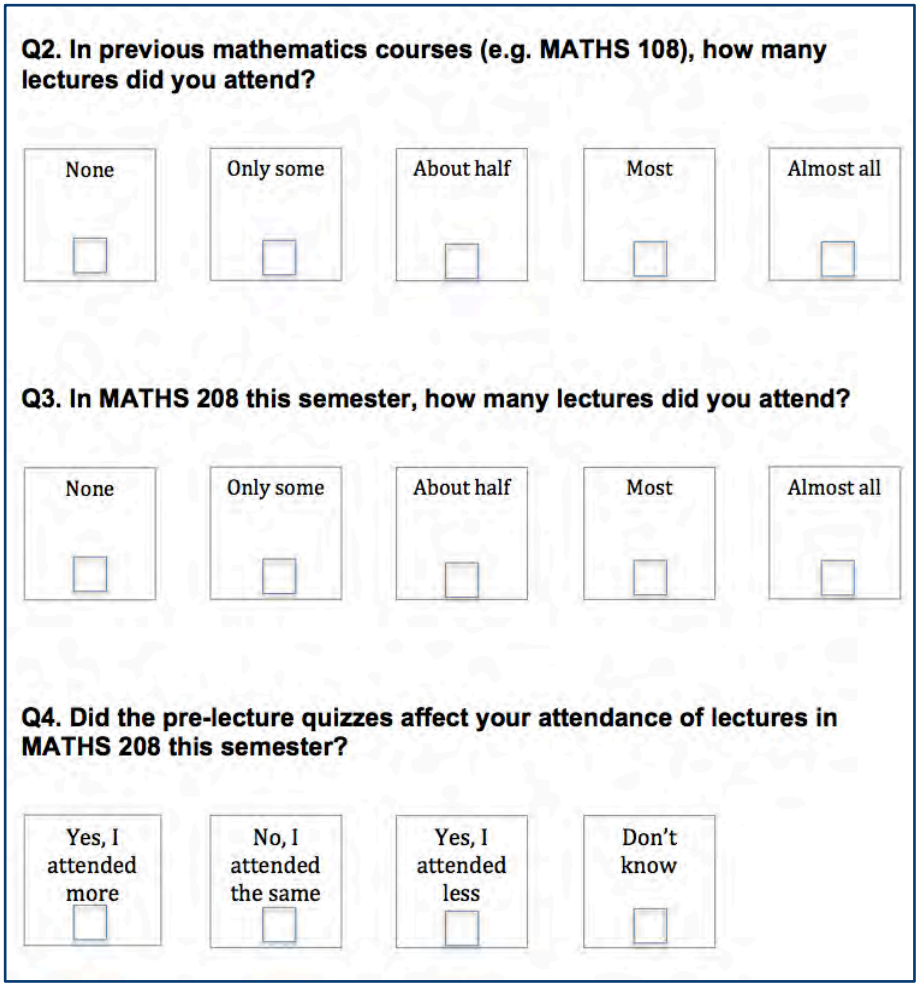
Magnitude of the impact of quizzes on students – the quizzes provided validation of their successful learning efforts (frequently), thus enabling the accumulation of their mastery experience.

Lecture attendance



Q2. In previous mathematics courses (e.g. MATHS 108), how many lectures did you attend?

None	Only some	About half	Most	Almost all
☐	☐	☐	☐	☐

Q3. In MATHS 208 this semester, how many lectures did you attend?

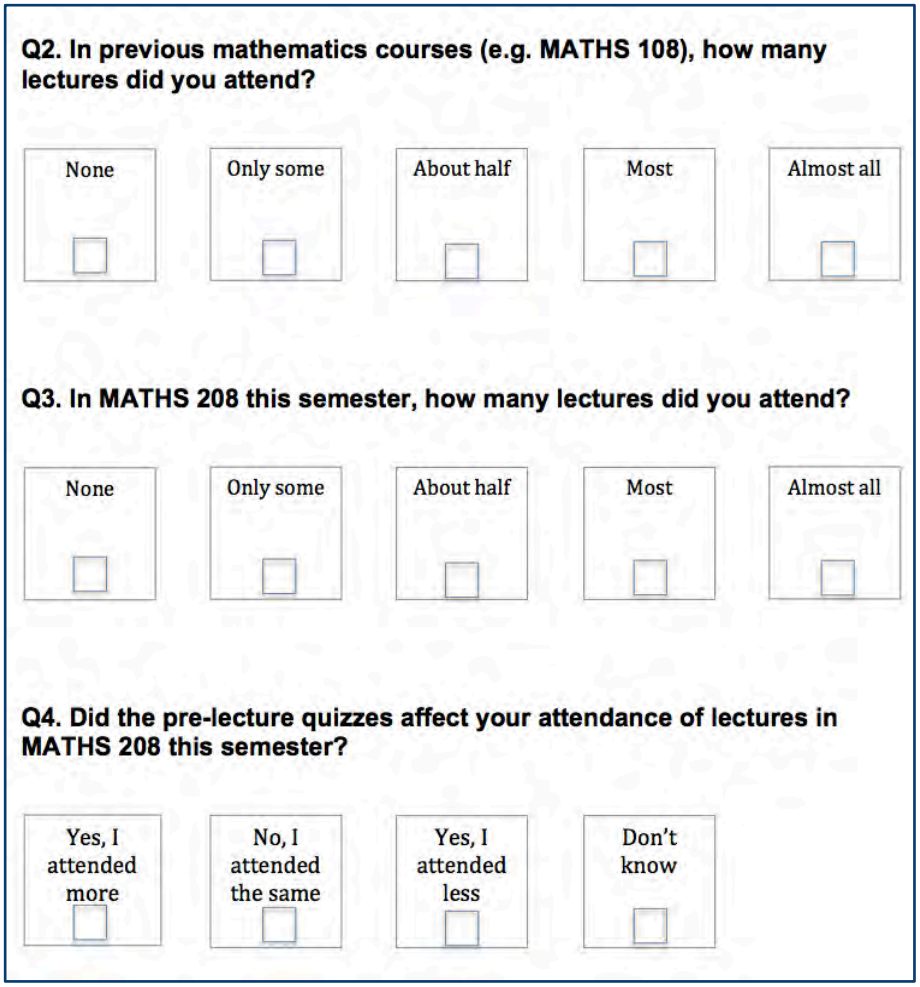
None	Only some	About half	Most	Almost all
☐	☐	☐	☐	☐

Q4. Did the pre-lecture quizzes affect your attendance of lectures in MATHS 208 this semester?

Yes, I attended more	No, I attended the same	Yes, I attended less	Don't know
☐	☐	☐	☐

Lecture attendance

- Self-reported increase in attendance was confirmed by categorical comparison ($\chi 2(4)=12.5$, $p=.014$, Cramér's $V=1.06$).



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Q3. In MATHS 208 this semester, how many lectures did you attend?

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Q4. Did the pre-lecture quizzes affect your attendance of lectures in MATHS 208 this semester?

Yes, I attended more	No, I attended the same	Yes, I attended less	Don't know
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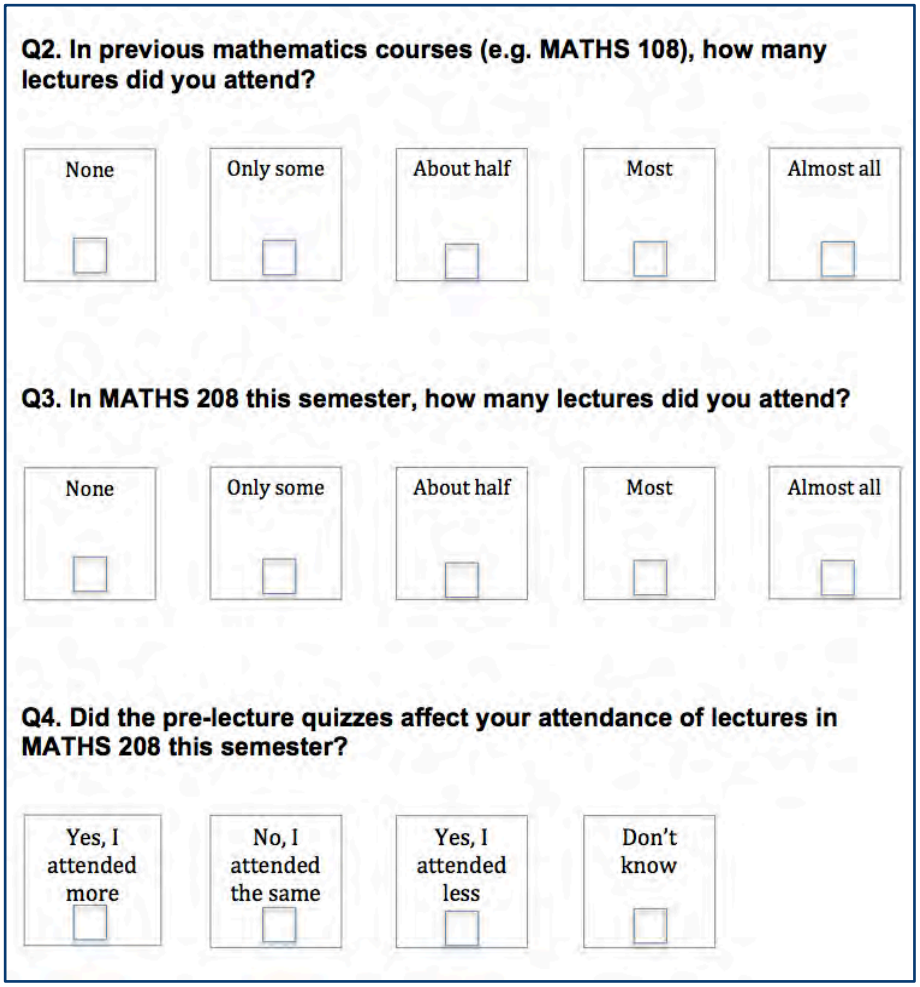
Lecture attendance

- Self-reported increase in attendance was confirmed by categorical comparison ($\chi 2(4)=12.5$, $p=.014$, Cramér's $V=1.06$).
- 27% of students admitted that pre-lecture quizzes in the trial semester affected their attendance ("Yes, I attended more").



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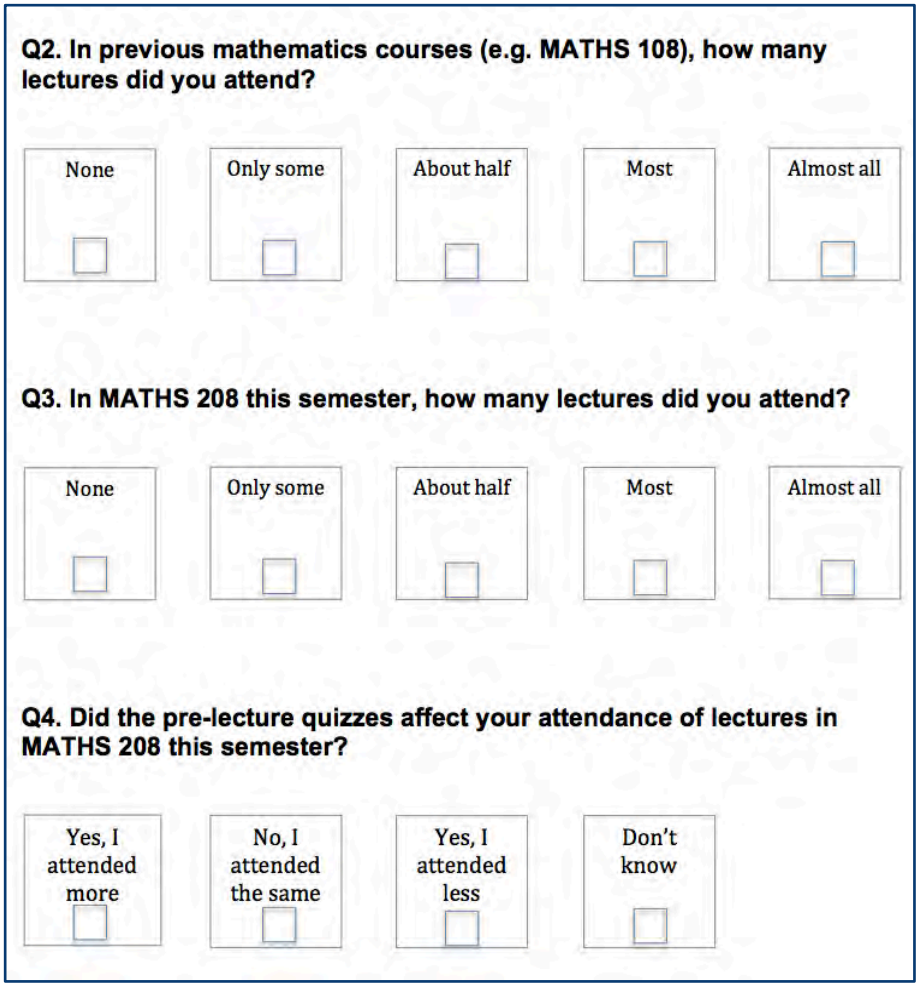

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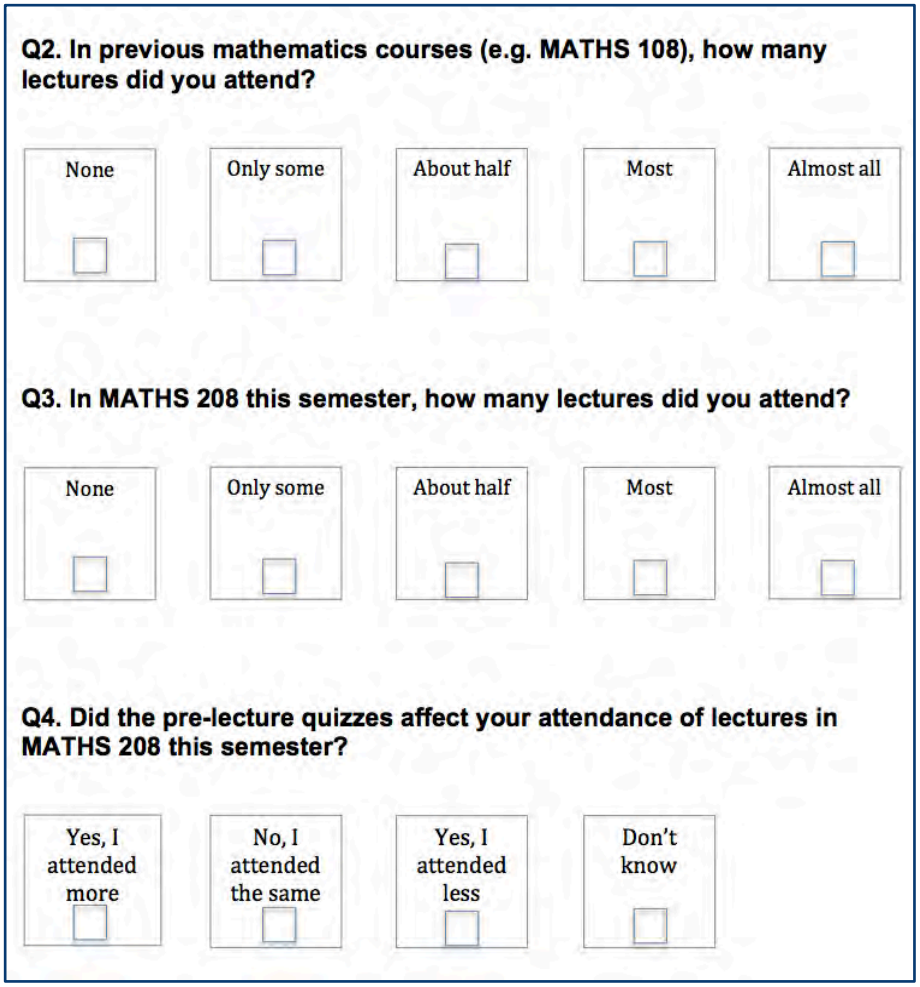

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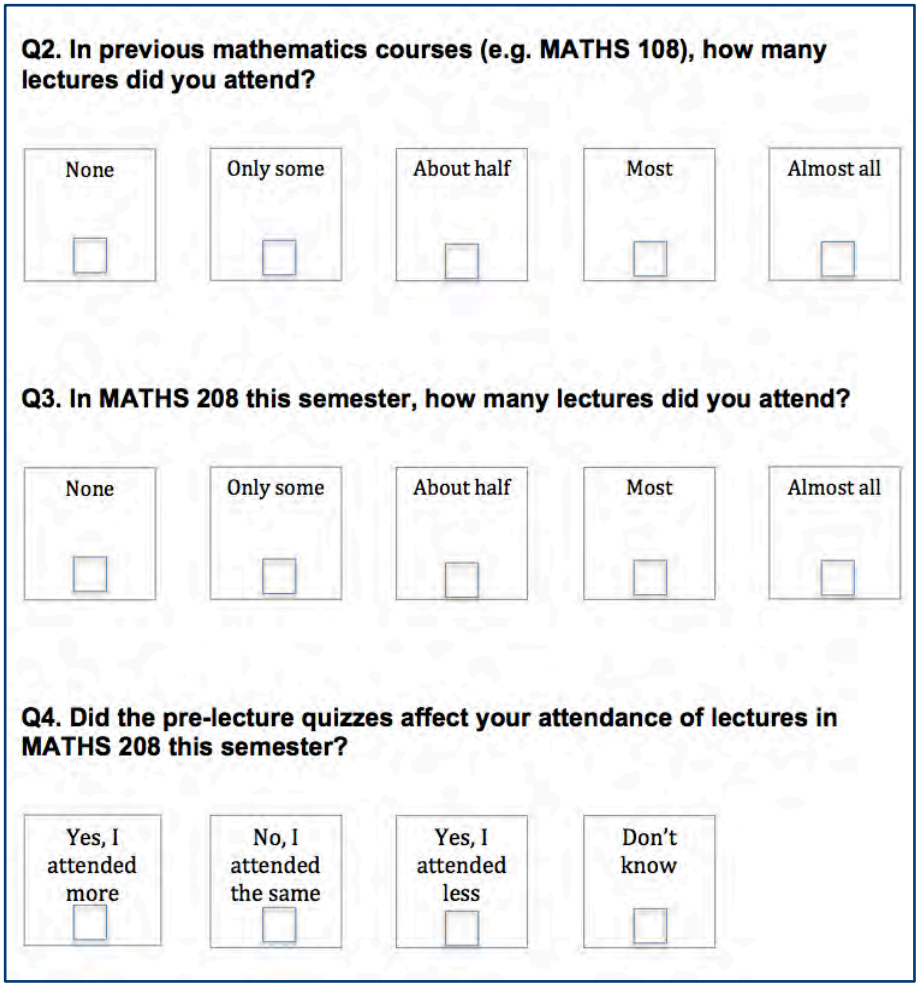
Overall, it is plausible to suggest that the intervention has made a positive impact on educational exchange in terms of improved lecture attendance.



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Focus group interview

Although a small group (5 students), and not necessarily representative of the whole class, it was interesting to gain insights about:

- how committed they were to the completion of the quizzes
- how they worked (guess work; collaborative environment)
- their explanations about the added-value of quizzes (regular revision and practice)
- their perspectives on instructional structure and motivational drivers:

> ” I think that, for some subjects, it is so easy to just turn up to lectures and to just turn up to tutorials and do the work and then if you forget about it until the next week, then that’s fine. But the quizzes in some way – you get home in the evenings and you like ‘Oh, I got to do my quiz’. So, you map stuff out…so you are more inclined to do things…yeah, it motivates me a bit more.”

Unanimously, all students agreed that incorporation of on-line quizzes was a good innovation for the mathematics course and suggested it should be used more widely.

Tutor interview

A tutor was employed to facilitate 10 out of 13 tutorial streams (300 students), who had also previously worked as a tutor for the same course for four semesters so was able to provide some insightful comparison:

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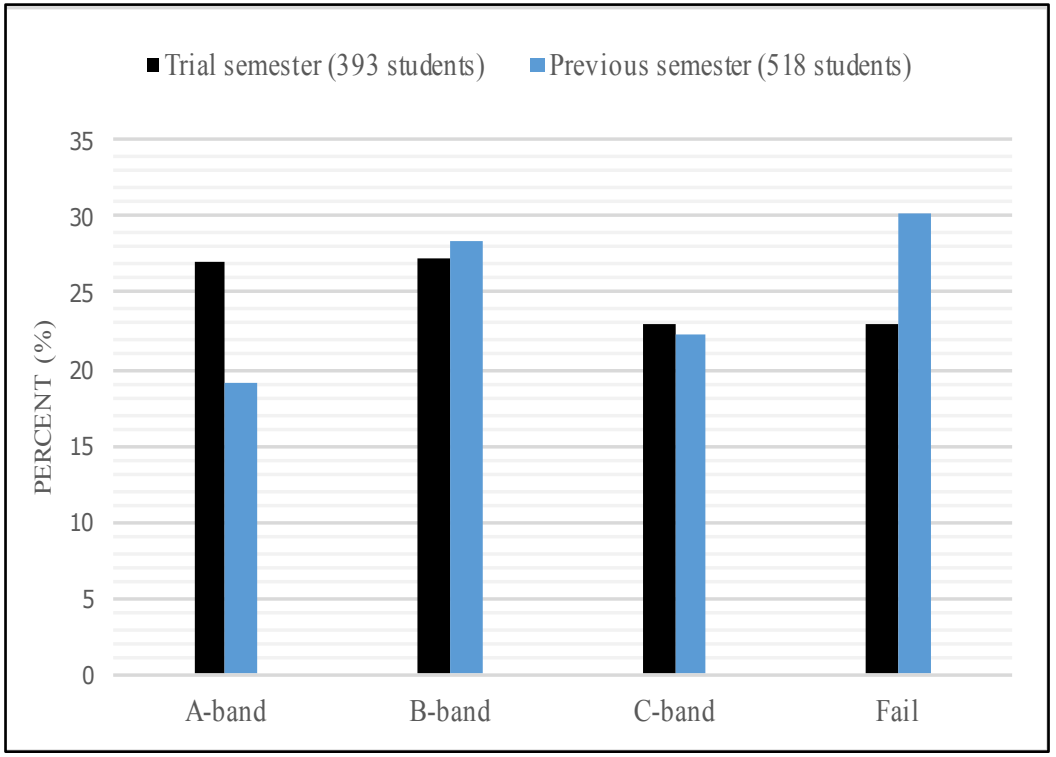
> "I did definitely notice that there was a smaller proportion of people coming into tutorials that had absolutely no idea what any of the questions were. So, a lot of the time in previous semesters it would become quite clear to me that people did not know much about what was going on because either they've been to class but did not really pay attention or haven't gone over their notes... And so, often I would explain a few things on the board at the beginning to get them started - that was last year... But this semester... it was easier on me. I could help them more in terms of the level that they should be at instead of starting from scratch."

Final grades: trial semester vs previous semester

While admitting the limitations of this approach, we note many similarities in the delivery of the courses:

- the same course coordinator,
- the same instructor (large part of semesters),
- the same course book and all other materials,
- identical split into lecture topics,
- the same external assessor.

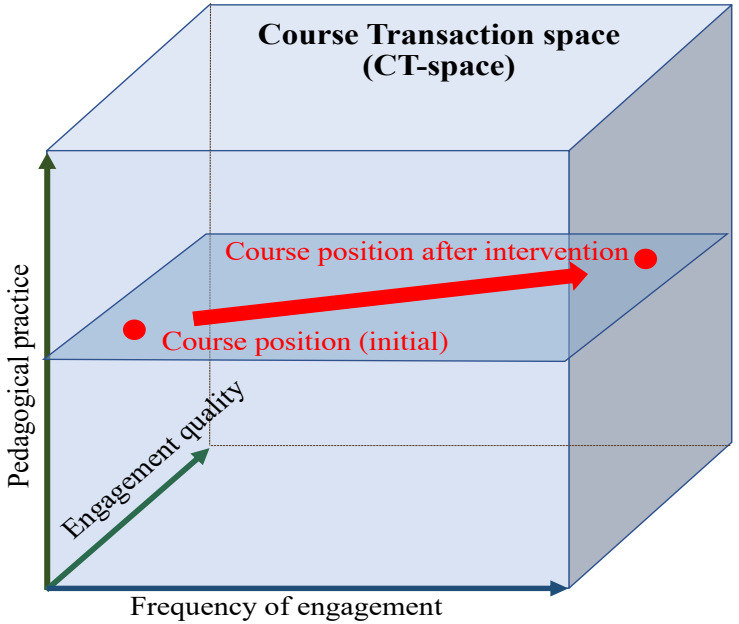


Observed: significant shift in course grades across the grade bands: from reduction in the proportion of fails to an increase (by almost identical amount) in A-band grades (Chi-square test: $\chi^2(3)=10.57$, $p=.014$).

Summary

Incorporation of quizzes – a relatively small change in course delivery can significantly improve the course 'coordinates' in the *CT-space*, indicating a more efficient and effective educational exchange.

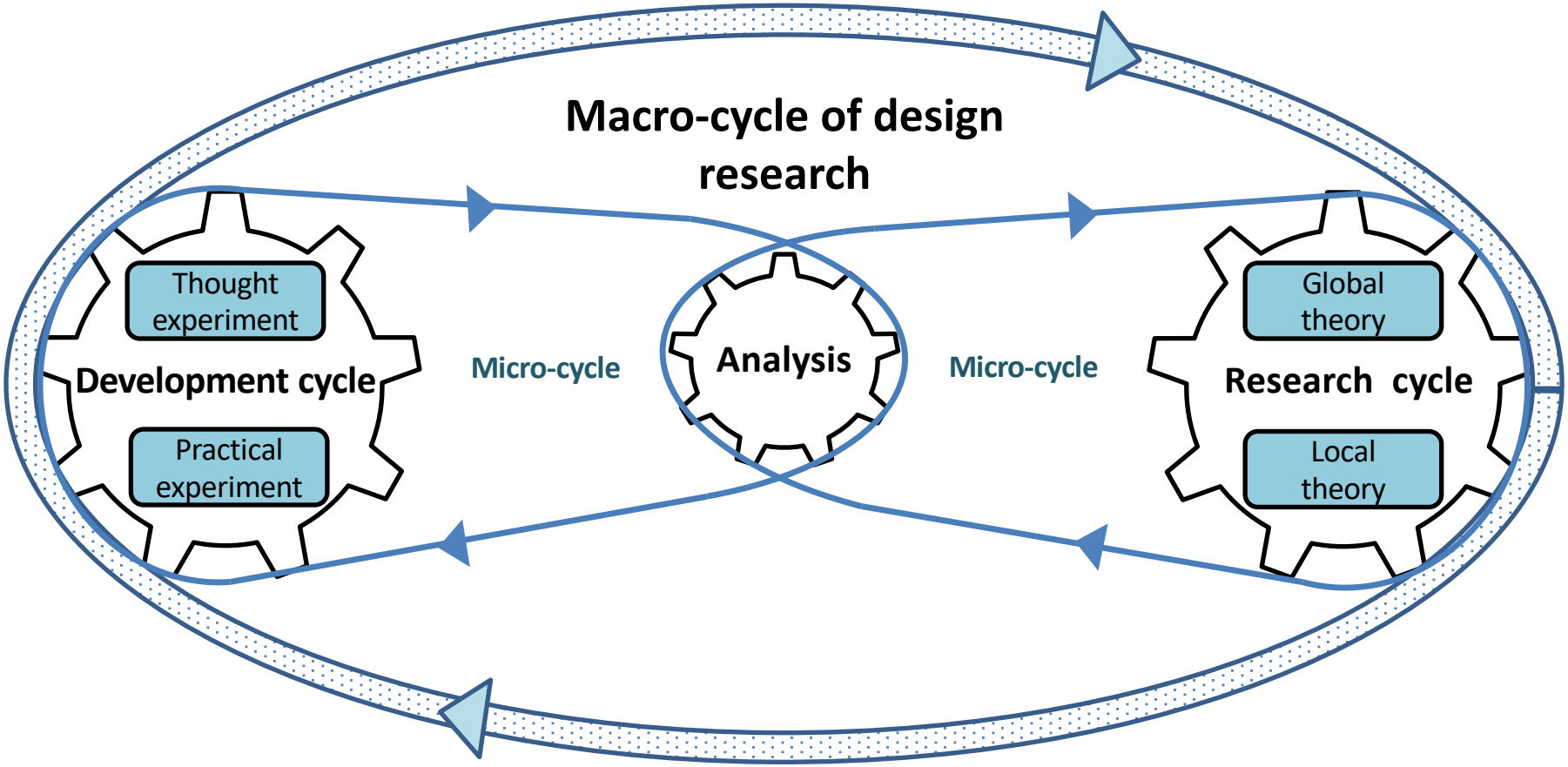
x-axis	• Frequency of learners' engagement with content
y-axis	• Quality of learners' engagement
z-axis	• Pedagogical practice



Mapping the impact of regular online pre-lecture quizzes:

- optimise the effect of distributed (spaced) practice
- improve quality of learners' engagement

Design research: ontological innovation



DiSessa, A., & Cobb, P. (2004). Ontological Innovation and the Role of Theory in Design Experiments. *The Journal of the Learning Sciences, 13*(1), 77-103.

Dissemination through Professional Development

Proposal for the field:

Theme 2: Investigating the mechanisms involved in successful professional development projects in mathematics departments and developing frameworks for dissemination of effective/efficient teaching and learning practices in a realistic departmental setting.

This largely unexplored area of research, if developed, can potentially have a major impact on the university mathematics education.

Successful PD project (2009 –)

DATUM - the **D**evelopment and **A**nalysis of the **T**eaching of **U**ndergraduate **M**athematics professional development discussion group.

Oates, G. & Evans, T. (2017). Research mathematicians and mathematics educators: collaborating for professional development. In K. Patterson (Ed.), *Focus on Mathematics Education Research* (pp. 1-30). New York: NOVA Science Publishers.

Paterson, J. E., & Evans, T. (2013). Audience insights: feed forward in professional development. In D. King, B. Loch (Eds.) *Shining through the fog: The 9th DELTA conference on undergraduate teaching and learning of mathematics and statistics* (pp.132-140). Kiama, Australia.

Schoenfeld, A., Thomas, M., & Barton, B. (2016). On understanding and improving the teaching of university mathematics. International Journal of STEM Education, 3(1), 1-17.

with Dr. Greg Oates

Current project: DATUM-2

Collaborator: Prof. Barbara Jaworski (Loughborough University)

- conducted in association with the PLATINUM project (an EU project – Erasmus+ involving 7 European countries)
- designed to establish Partnerships in Learning and Teaching in University Mathematics.

Thank you!


THE UNIVERSITY OF
AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

Thank you!

Doctoral Research Fellowships in Mathematics Education
Full-time (3 years), fully funded!

Supervisors: Igor' Kontorovich and/or Tanya Evans

Application due: 15 December, 2019

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