

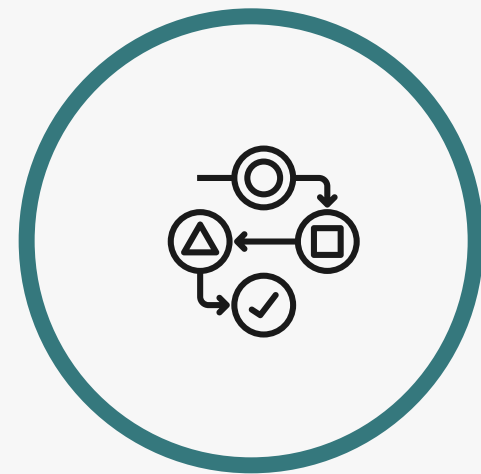
Connecting the curriculum:

Investigating the impact of competency-based curriculum on concept integration across chemistry modules and students' self efficacy



INTRODUCTION

LITERATURE
REVIEW



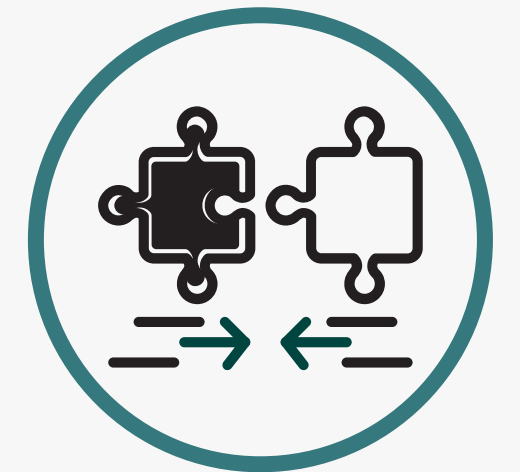
METHODOLOGY

KEY
FINDINGS



LIMITATIONS &
CONCLUSION

IMPLICATIONS



OUR CURRICULUM CHALLENGES



Fragmented Learning

Students tend to focus on completing assessment within individual modules, resulting in fragmented learning. This limits their ability to connect and integrate concepts across modules which is a critical skill in organic chemistry (Anzovino & Bretz, 2016)



Knowledge retention

Topics assessed in the first term are often not examined again in second term, students have little incentive to revisit prior content leading to knowledge decay and undermine their ability to build on earlier concepts in subsequent modules (Bunce et al., 2011; Carpenter et al., 2022).



Surface Learning

Traditional assessments remain the predominant form of assessment in our curriculum. As questions can be answered through memorisation alone, students are geared towards surface learning rather than understanding underlying principles, making it difficult for them to apply what they know when topics get more complex (Grove & Bretz, 2012).



Lacking Formative Feedback

In our curriculum, feedback is primarily given after high stakes assessment which is then too late to address misconceptions meaningfully. The absence of timely formative feedback leaves students unable to monitor their progress, contributing to uncertainty about their own understanding (Öz, H. 2025)

OUR INTERVENTION

Curriculum Challenges



Why connecting concepts is important in addressing curriculum challenges

- To master organic chemistry concepts, students have to connect and integrate concepts across related topics (Grieger & Leontyev, 2025)
- Students often struggle to see organic chemistry in a big picture and often treat each reaction as an isolated fact to be memorized
- Ability to link prior knowledge to new concepts is essential for meaningful learning.

Our intervention: Creative exercises

Creative exercises (CE)

A form of assessment in which students are given a prompt and asked to write as many distinct, correct and relevant facts about the prompts (Lewis et al., 2010)

Grounded in constructivism

Learning happens when students actively construct knowledge through learning activities (Lewis et al., 2010, 2011; Nix et al., 2023; Warfa & Odowa, 2015; Ye & Lewis, 2014)

Draws on Assumptive learning theory

Meaningful learning means students link concept instead of treating them in silos (Ausubel et al., 1978)

LITERATURE REVIEW

CEs are valid & effective

- CEs are valid and reliable assessment tool used to measure students' academic achievement
- In a study relating to computer science, studies show that implementing CEs is associated with higher grades and test scores, regardless of students' motivation and self regulation (Peteranetz et al., 2017)

CEs reveals misconceptions

- CEs can help instructors to identify students' misconceptions, which effectively identifies struggling students (Lewis et., 2010; Ye & Lewis, 2014)
- This allows for instructors to design targeted aid to address gaps before students progresses

CEs have been explored in several disciplines

- CEs have been used as an assessment tool in organic chemistry (Grieger & Leontyev, 2025)
- Even in the domain of biochemistry to link chemical and biochemical concepts (Warfa & Odowa, 2015)
- CEs are also incorporated to promote meaningful learning inorganic chemistry (Shaw, 2023)

WHY WE DID WHAT WE DID

CE in Polytechnics

Existing studies have largely reported on the use of CE within a single module, with limited research examining its implementation across multiple modules. Our investigation of CEs across modules could provide insights into the transfer of knowledge between contexts

Self-efficacy in CE

While existing studies have examined CE performance and student perceptions, the relationship between CE and students' self efficacy has not been investigated

Our research question

What are learners' perception of CE and its impact on their self- efficacy



Research setting

- **Institution**

Nanyang Polytechnic (Singapore)

- **Participants**

Year 1 students enrolled in Diploma in Applied Chemistry

- **Context**

Two CEs administered across two different organic chemistry modules.

= CE 1 : Chemical Structures & Reactivities

= CE 2 : Organic Methodologies

- **Sample size**

= CE 1 : n = 54

= CE 2 : n = 58

= Survey : n = 51



Quantitative analysis

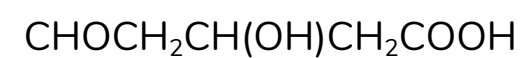
- For each CE, student's statements are scored 0, 1 and 2 with a maximum total of 10 points. Mean scores were calculated across all participants.
- Self efficacy was measured using Motivated Strategies for Learning Questionnaire (MSLQ) performance scale. Students rated items on a 7 point Likert scale.



Qualitative analysis

- Open-ended short answer responses were analysed using thematic analysis.
- Four key themes emerged: Concept Linking & Integration, Recall & Self assessment, Positive engagement, Challenges .

Creative exercise (CE 1)



Write down five correct, distinct and relevant facts or statement about the molecule.

Statement 1

Enter your answer

Statement 2

Enter your answer

Statment 3

Enter your answer

Statement

Enter your answer

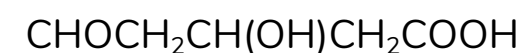
Statement 5

Enter your answer

Instructions

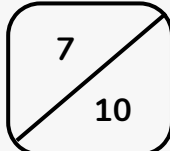
- CEs were administered during class time three to four weeks after module content delivery.
- Students completed the CE by scanning a QR code linked to a Microsoft Forms survey.
- Students were required to provide 5 accurate, distinct, and relevant statements about a given molecule/reaction.
- Responses were completed without reference to notes or the internet, ensuring independent recall.

Creative exercise (CE 1)



Write down five correct, distinct and relevant facts or statement about the molecule.

Statement	Score
Statement 1 It has an tertiary alcohol group	1
Statement 2 It has an alkene functional group	0
Statement 3 The molecular formula is C ₅ H ₈ O ₄	2
Statement 4 It has an aldehyde functional group	2
Statement 5 Carbon 3 is chiral	2

Total Score




Analysis

- Each of the 5 statements was scored using a 3-point rubric
 - 2 = Statement is correct and relevant
 - 1 = Statement is partially correct and/or relevant
 - 0 = Statement is incorrect and/or irrelevant
- Total score per student was summed (max = 10)
- Mean score was calculated across all participants

$$\text{Mean} = \frac{\sum (\text{Total scores})}{N}$$

Survey on Concept integration

Provide a response from a scale of (10 = Not at all true to me to (7)= very true of me for the following statements

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

2. What i found useful about the activity ?

Enter your answer

3. What i like or dislike about the activity ?

Enter your answer



Instructions

- A survey was administered to student upon completion of the CE.
- Self-efficacy was measured using the MSLQ performance scale
- Student rated each statement on a 7 point Likert scale (1)= Not at all true of me (7)= Very true of me
- Self-efficacy was measured using one of the dimensions (Self-efficacy for learning and performance) from the MSLQ instrument
= “What did you find useful about this activity ? ”
= “What did you like or dislike about this activity ? ”

Survey on Concept integration

1. Provide a response from a scale of (10 = Not at all true to me to (7)= very true of me for the following statements

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

• xxx

2. What i found useful about the activity

Enter your answer

3. What i like or dislike about the activity

Enter your answer



Analysis

- 8 items were rated on a 7-point Likert scale
(1)= Not at all true of me
(7)= Very true of me
- Sample items:
= “I believe i will receive an excellent grade in this module”
= “I expect to do well in this module”
- For each item, the following were calculated
= Mean : average self-efficacy rating across all participants
= Standard deviation (SD) : spread of responses per item

 **CE Scores****DESCRIPTIVE STATISTICS**

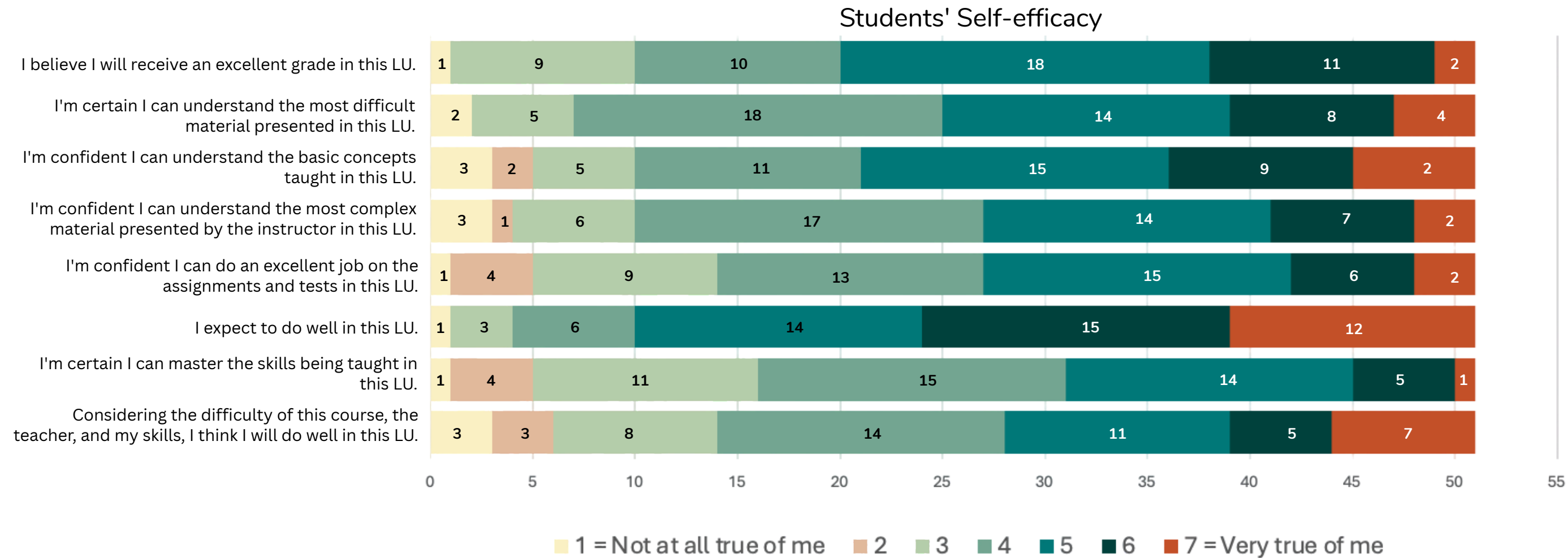
CE	Sample size	Mean
CE 1	54	7.69
CE 2	58	8.74

INTERPRETATION OF CE SCORES

- Students across both modules demonstrated strong conceptual understanding, with high mean CE scores:
 - CE 1 (n = 54): M = 7.69 / 10
 - CE 2 (n = 58): M = 8.74 / 10
- Majority of the statements written were correct and relevant, indicating effective recall and connection of organic chemistry concept across the two modules.



Survey on Students' Self-efficacy



STUDENT PERCEPTIONS OF CE USEFULNESS

Students found CEs more useful for foundational concepts than challenging ones:

- Foundational concepts: M = 5.45, SD = 1.32
- Challenging concepts: M = 4.10, SD = 1.25

GRADE EXPECTATION

Students held moderate expectations for achieving an excellent module grade:

- M = 4.37, SD = 1.64 (on a 7-point scale)
- The higher SD suggests varied confidence levels across the cohort

Student perceptions of CEs

- Open-ended survey responses were analysis using thematic analysis
- Responses were systematically reviewed to identify reccuring patterns in how students described their experience of completing CEs.
- 4 themes emerged from their responses



Concept Linking & Integration

Able to connect ideas across the two LUs



Recall & Self assessment

Gauging what they already know and identifying gaps



Positive engagement

Positive responses when completing the CEs



Challenges

Difficulties encountered and suggested areas for improvement

Theme 1

CONCEPT LINKING & INTEGRATION

Students frequently described the CEs as helping them to connect knowledge across the two organic chemistry modules.

“STUDENTS’ VOICES”

“It helps me to draw links between different topics and modules”

“Helps to bring together different topics”

“Amazing for cross linking and applying concepts”

“It helps me to link concepts between modules to bridge learning gaps and allows me to have a cohesive and comprehensive understanding of chemistry”

Theme 2

RECALL & SELF ASSESSMENT

Students found CEs useful for gauging their own understanding, allowing them to identify gaps in their knowledge and also take ownership of their learning

“STUDENTS’ VOICES”

“ Helps me to recap what I have learnt in the past”

“ Helps us to revise”

“It helps me understand how much i understood and what i need to work on”

“Makes me recall the previous week’s contents which I would normally not think of ”

Theme 3

POSITIVE ENGAGEMENT

Students expressed genuine enjoyment of the activity fostering positive experience

“STUDENTS’ VOICES”

“I enjoy the simplicity of it, and the fact that I can draw from multiple topics”

“I like the part where nobody knows what mistakes i made ”

“I like how it makes me reflect on the things I’ve learnt”

“I like the activity because it’s fun and helps me practice active recall to help retain lecture materials ”

Theme 4

CHALLENGES

While students are generally receptive to CEs, some expressed difficulty generating 5 statements without other resources

“STUDENTS’ VOICES”

“ 5 Statements are too many to think of”

“ The duration of the activity is a bit long”

“A lot of memorisation”

Learner's perception of creative exercises

- Students perceived CEs positively as an engaging learning activity.
- CEs were valued for supporting knowledge integration across the two organic chemistry modules.
- Students also recognised CEs as a self-assessment tool to help them gauge their understanding and identify learning gaps.
- However, some students found difficulty in generating five accurate statements, suggesting adjustments to the number of required statements may better support learner confidence

Impact on self efficacy

- Students reported moderate confidence for foundational concepts and lower confidence for more challenging material
- Grade expectations were moderate, reflecting uncertainty about overall performance in the modules.
- Self-efficacy remained largely at the midpoint across 7 out of 8 MSLQ items, despite positive perceptions of the CE activity
- Strong CE performance did not automatically translate into higher confidence — suggesting a gap between actual ability and perceived capability

Learner's perception of creative exercises

- Students perceived CEs positively as an engaging learning activity. Which aligns with existing literature, where CEs have been shown to give students a sense of pride and accomplishment (Lewis, Shaw & Freeman, 2010)
- Difficulty of generating five accurate statements likely reflect cognitive demands of independent recall without resources, particularly complex chemistry concept.
- The perception of CEs as a concept linking tool aligns with Ausubel's assumptive learning theory where learning is more meaningful when concepts are consciously anchored to existing concepts rather than understanding it in isolation. Students themselves identified concept linking as a feature of CEs suggest that they are actively relating the content from one module with another. Such awareness is noteworthy as meaningful learning requires an intention to connect.

Impact on self efficacy

- Despite strong CE performance and positive perceptions of concept linking, self-efficacy score remained moderate. This may suggest a disconnect between actual ability and perceived ability.
- While students responded positively to the open ended format of CEs which supports learner agency, their moderate self-efficacy scores may reflect the influence of other factors such as unfamiliarity of such assessment type

SELF EFFICACY MEASURED AT ONE TIME POINT

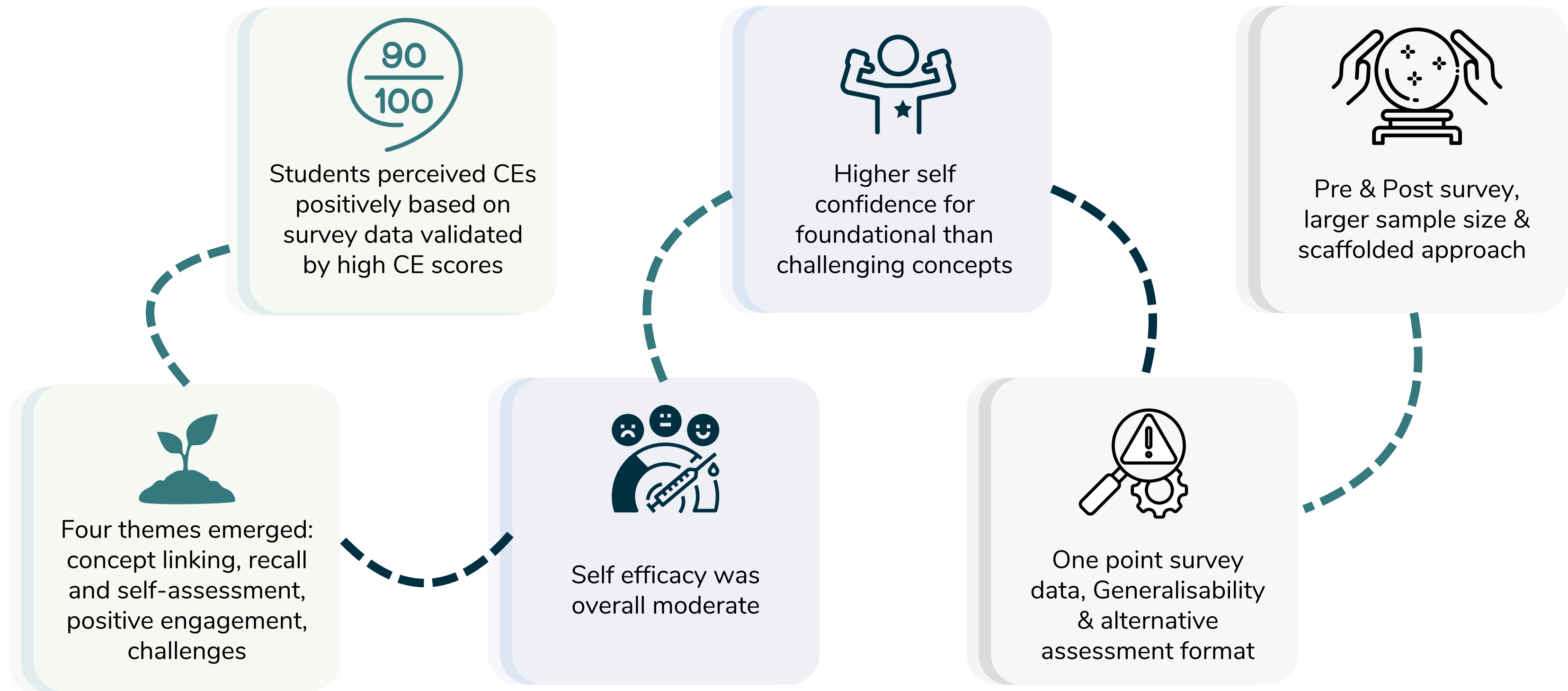
- MSLQ survey was administered at only at one time point upon completion of both CEs which may limit the ability to determine whether CEs influenced students self-efficacy.
- Since self-efficacy is constructed through repeated experience, a pre and post survey would provide a stronger evidence of the CE actual impact on learner self efficacy

GENERALISABILITY

- This study was conducted within a single year 1 cohort of one diploma program. this limits the generalisability of findings to other year groups, disciplines or institution
- Future studies should explore CE implementation across the three years of Diploma in Applied Chemistry to study its effectiveness and the impact on self-efficacy

ALTERNATIVE FORM OF ASSESSMENT

- CEs are an alternative form of assessment in chemistry education especially with an element of creativity which could influence the performance and self- efficacy score
- This could be mitigated by a scaffolded approach by introducing CEs as formative assessment through learning activities



MEANINGFUL LEARNING

CEs promotes meaningful learning over rote memorization that students tend to focus. CE requires student to apply and connect concept to move beyond surface recall

SPOTTING MISCONCEPTION

CE can serve as a diagnostic tool implemented in modules so misconceptions can be identified before student progress to more advanced topics

CONNECTED LEARNING

CEs can be designed explicitly to bridge content across related modules

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