Enhancing Programming Learning with AI Generated Contextual Examples in Digital Creativity

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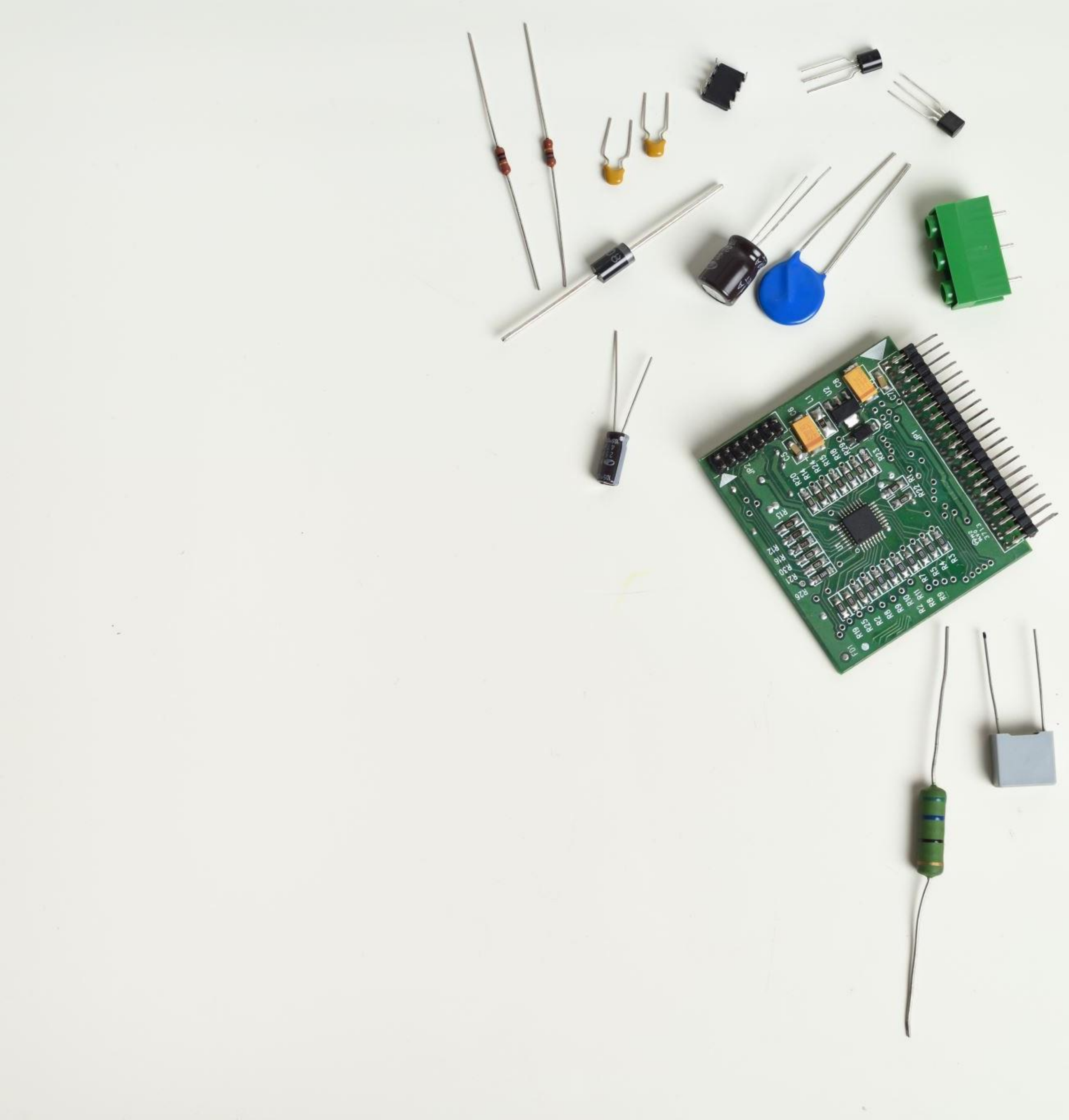

Introduction

- Stage 1 module in Digital Creativity
- 200-300 students
- Students create a virtual diorama using C#
- Multidisciplinary
  - Art, Design, Music, Programming, Writing, etc.

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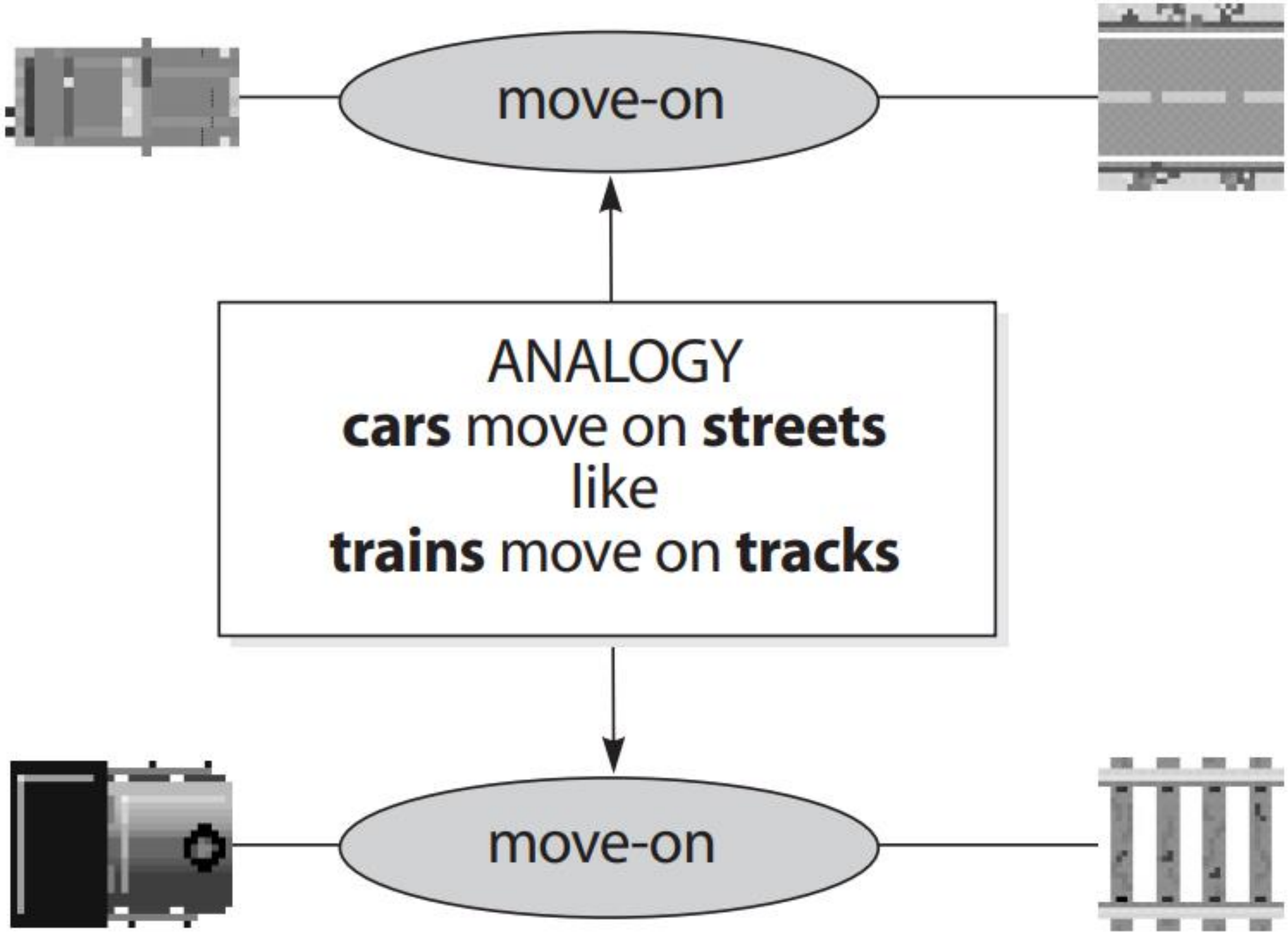
Analogous Examples

> "Analogies are powerful cognitive mechanisms that people use to construct new knowledge from knowledge already acquired and understood…The combination of PBE with analogies is called Programming by analogous examples."

Repenning & Perrone (2000)



ANALOGY
cars move on **streets**
like
trains move on **tracks**

Contextual Examples

> "Context works if it’s related to the participant’s own experience: performance on the selection task is significantly facilitated when the presentation of the task allows the subject to recall past experience with the content of the problem, the relationship expressed, and a counter-example to the rule governing the relationship."

Griggs and Cox, 1982

Contextual Examples

A contextual example is a form of analogous example that is actively situated in a context that allows for recall of prior knowledge to enable the thematic facilitation of further learning

Challenges

- Matchmaking to situate examples in a relatable disciplinary context based on a student's background
- Tailoring material can be onerous and time-consuming to prepare; particularly in diverse modules that include learners from a wide range of backgrounds

Prior Work

- Brusilovsky (2001) proposes adaptive hypermedia systems
- Lubart (2005) outlines four ways computers can facilitate creativity: managing; supporting communication between collaborators; enhancing creativity; and cooperating in creative acts
- Mampadi *et al* (2011) show that adaptive hypermedia systems to tailor educational material to cognitive styles enhances learning
- Wikis increase in popularity, with potential for adaptive teaching of computing (Kim, Han & Han, 2006; González-Ortega et al, 2010; Lin, Wu & Chiu, 2018)
- Problem descriptions don't seem to help or hurt, beyond motivation, but studies focused on task instructions rather than contextualizing teaching material and have limited individualisation (Bouvier et al, 2016; Craig, Smith, and Petersen, 2017)

Prior Work

- Leinonen, Denny & Whalley (2021) find ontextualised problem solving in a programming contexts does help, but familiarity and underlying mathematics skills moderate the benefit
- Considerable research on the educational impact of ChatGPT on learning programming, showcasing its potential to automatically contextualise examples (Balse *et al*, 2023; Biwas, 2023; Ouh *et al*, 2023; Leinonen *et al*, 2023; Tian *et al*, 2023; etc.)
- Daun and Brings (2023) outline the threats and opportunities of ChatGPT for software engineering education, including the individualisation of education
- Chen *et al* (2023) present a ChatGPT-driven intelligent tutoring system for code explanation

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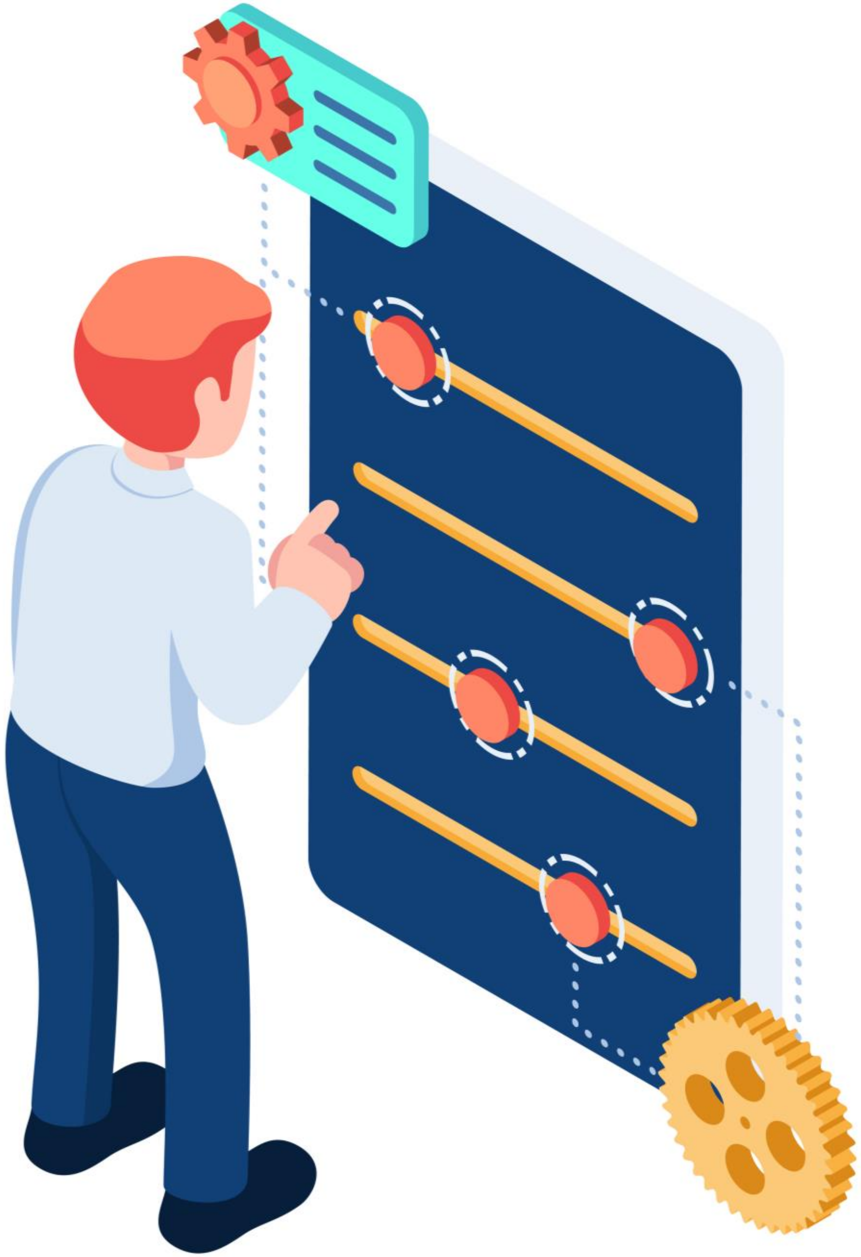
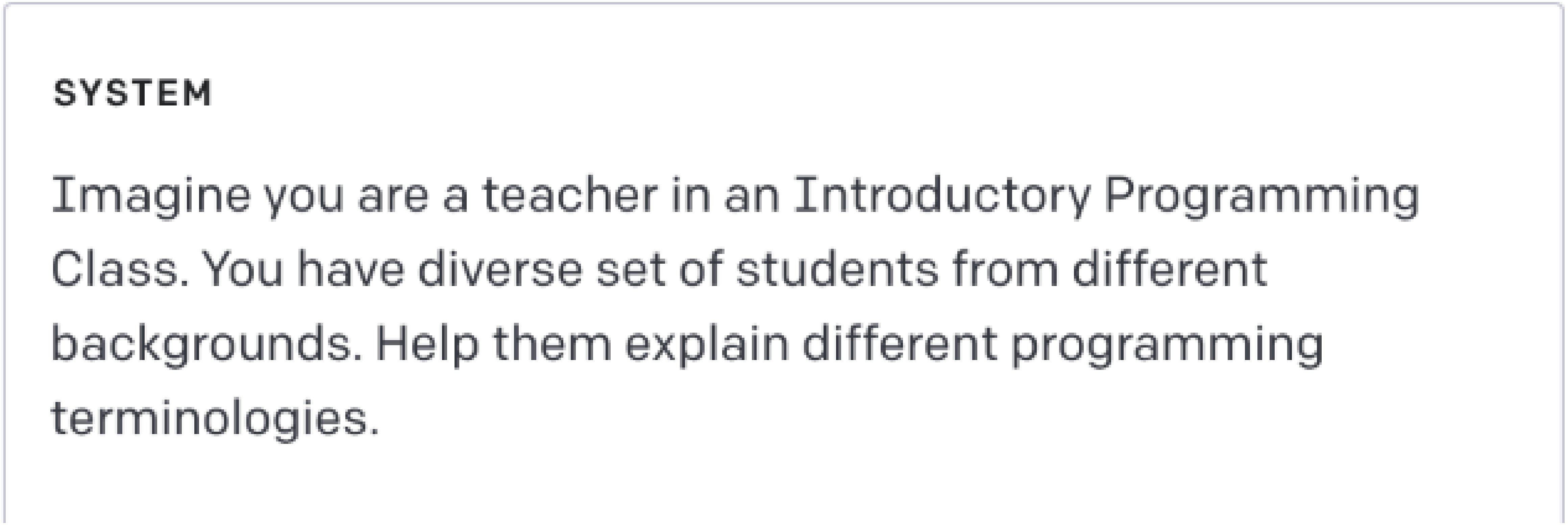
Research Question

To what extent does using ChatGPT to tailor contextual examples of programming concepts to disciplinary domains improve how students of those disciplines learn those programming concepts?



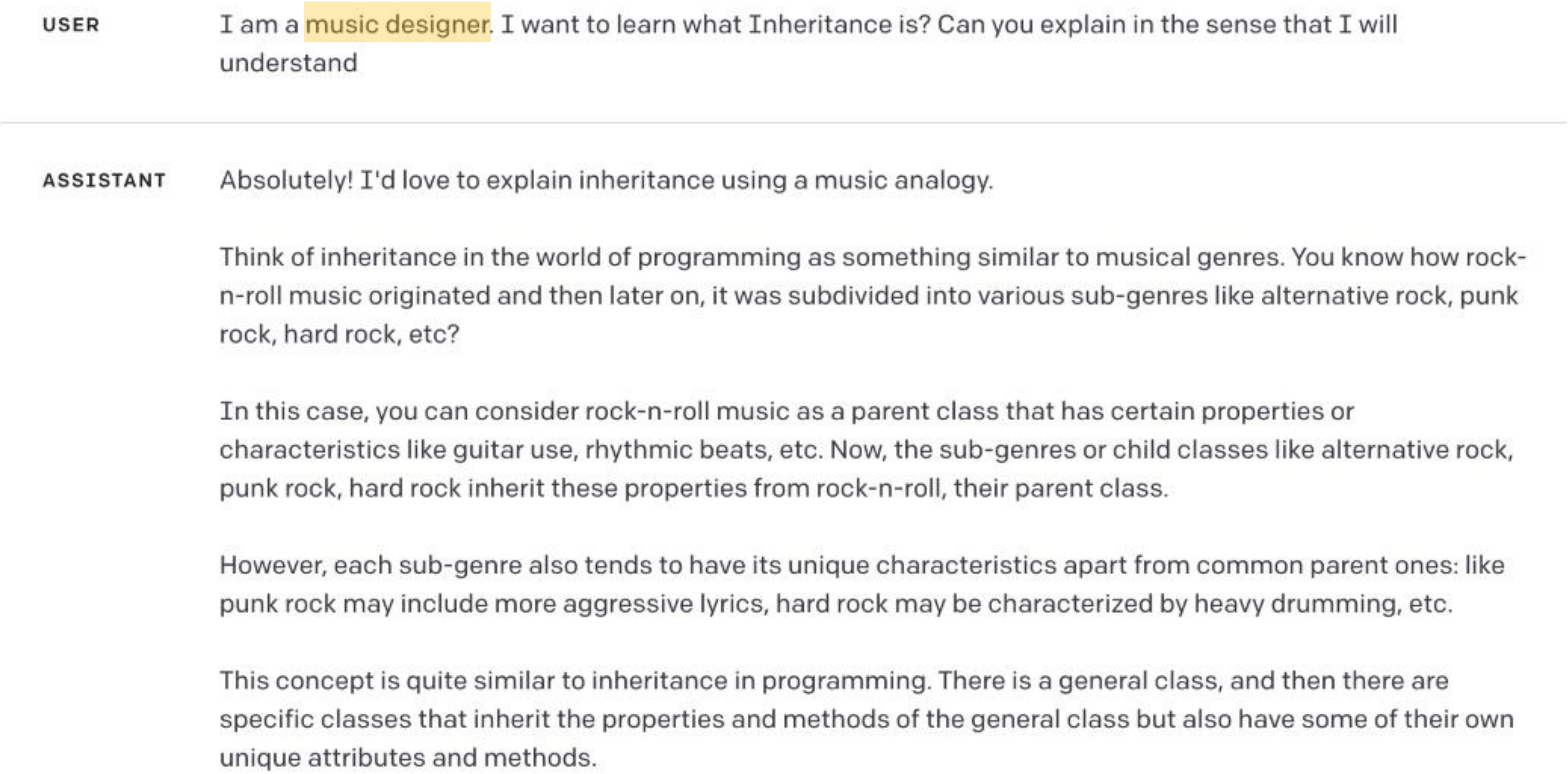
Tailoring Examples

- Wiki system integrated into our virtual learning environment, Moodle
- Currently populated with material about programming concepts typically encountered in CS1 and CS2 contexts
- Adding contextualised examples for 23/24
- Using ChatGPT (GPT-4) to produce analoguous examples for each disciplinary grouping: artist, designer, musician, programmer, writer, etc.
- Using a GET request (setup using a course variable in Moodle's URL resource) to display the correct version of the wiki page for students on each course



SYSTEM

Imagine you are a teacher in an Introductory Programming Class. You have diverse set of students from different backgrounds. Help them explain different programming terminologies.



USER I am a music designer. I want to learn what Inheritance is? Can you explain in the sense that I will understand

---

ASSISTANT Absolutely! I'd love to explain inheritance using a music analogy.

Think of inheritance in the world of programming as something similar to musical genres. You know how rock-n-roll music originated and then later on, it was subdivided into various sub-genres like alternative rock, punk rock, hard rock, etc?

In this case, you can consider rock-n-roll music as a parent class that has certain properties or characteristics like guitar use, rhythmic beats, etc. Now, the sub-genres or child classes like alternative rock, punk rock, hard rock inherit these properties from rock-n-roll, their parent class.

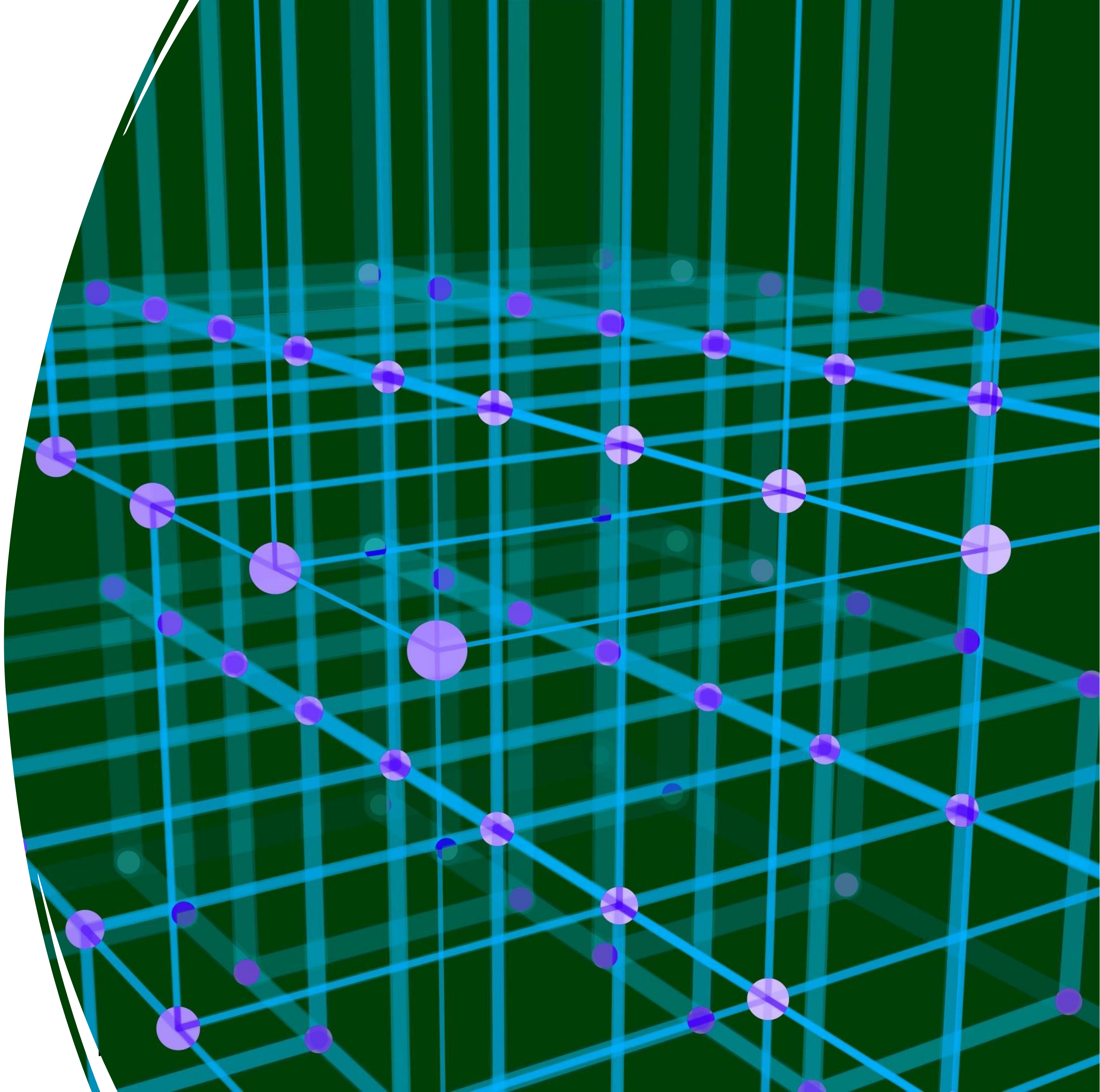
However, each sub-genre also tends to have its unique characteristics apart from common parent ones: like punk rock may include more aggressive lyrics, hard rock may be characterized by heavy drumming, etc.

This concept is quite similar to inheritance in programming. There is a general class, and then there are specific classes that inherit the properties and methods of the general class but also have some of their own unique attributes and methods.

Method

Pilot

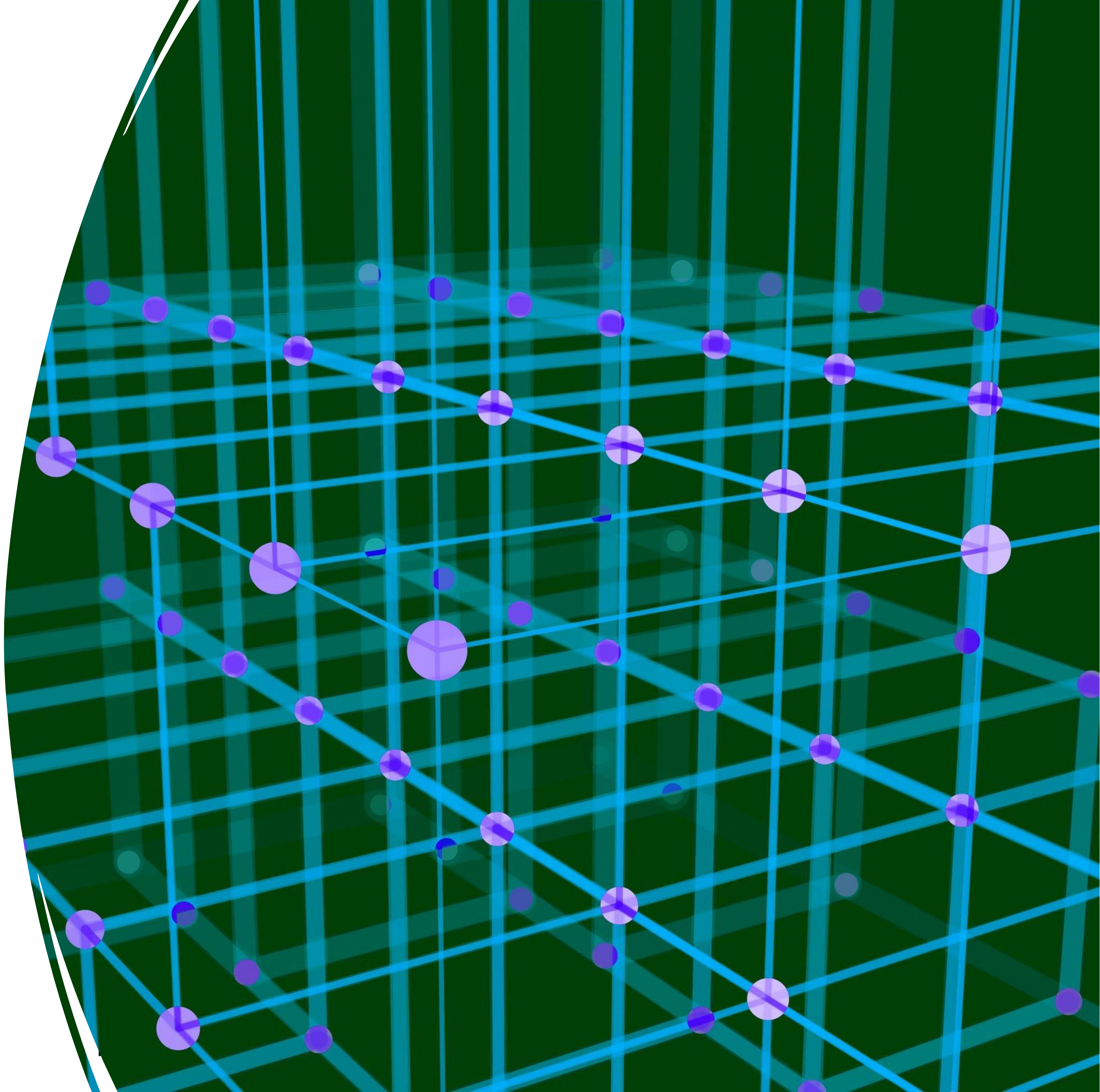
- Explanations were generated for object-orientated concepts (inheritance, polymorphism, abstraction, encapsulation) and circulated for comment
- Rated for "face validity" on a 3-point scale (bad, okay, good)
- Convenience sample of 10 colleagues in art, design, writing, etc. compared the existing example to the generated contextualised example
- Reviewed difference



Method

Future Study

- Experiment
- Three groupings:
  - Contextualised (Matched)
  - Contextualised (Mismatched)
  - Non-contextualised
- Three workshops:
  - Flow control structures
  - Inheritance and polymorphism
  - Common data structures
- Random allocation, within-participant



Method

	Flow Control	Inheritance and Polymorphism	Common Data Structures
Contextualized (Matched)	Group A	Group C	Grouo A
Contextualized (Mismatched)	Group B	Group A	Group C
Non-Contextualized	Group C	Group B	Group A

Each grouping is randomly allocated and will include students from across all the courses. The virtual learning environment will be set up to direct each individual student to the relevant wiki page based on their course enrollment and experimental grouping.

Pilot Findings

- Some of the generated examples are quite compelling
- Others need considerable tweaking in both the prompt and returned explanation
    - "Character artist" gave examples that were more closely tied to designers than artists, focusing on a fantasy role-playing game
- Initial evidence for face validity in comparing generated to existing

Considerations

- Would colleagues feel similarly positive in a blind review of examples?
- Will the wider student body receive the intervention as enthused as colleagues in the pilot?
- Will students reject expansions of our teaching material facilitated using artificial intelligence?
- What is the proportion of good tailoring to bad tailoring?
- Who owns the intellectual property for the wiki content?
- Who maintains the wiki content?
- Will bad content in the wiki undermine confidence?
- What level of regeneration/editing is still required?
- Will students spot and fix issues in the wiki?

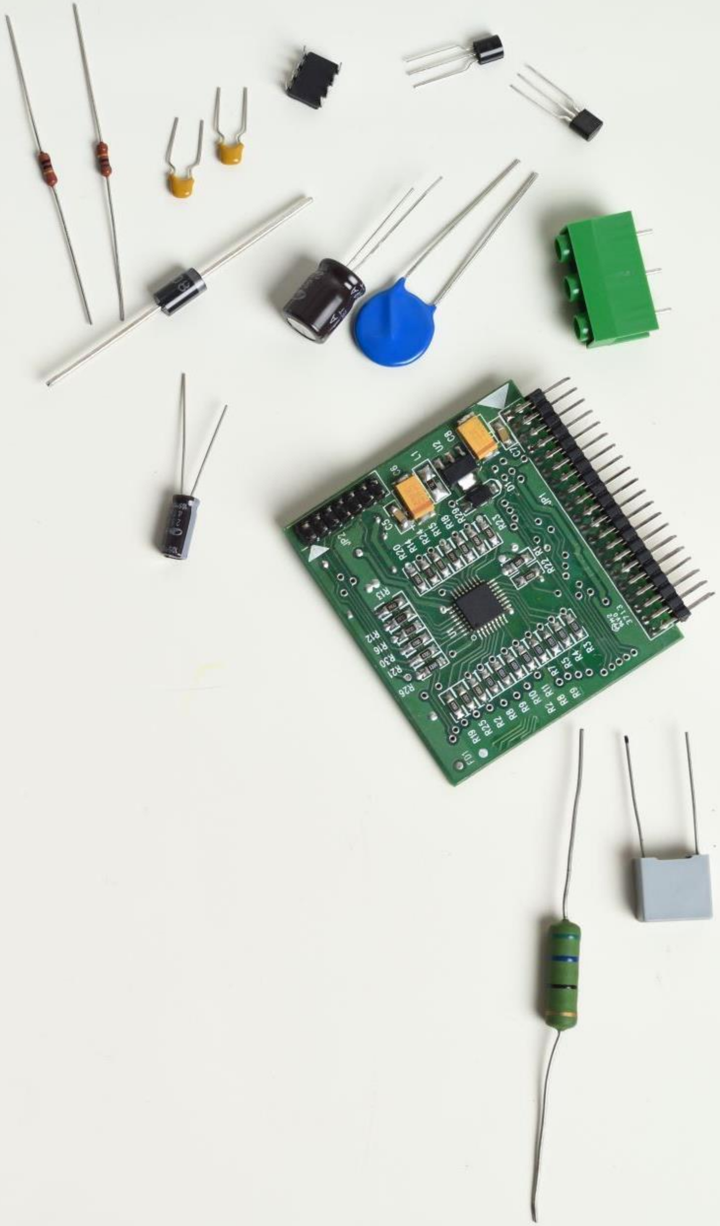
Further Work

Larger-scale rollout and trial in the Digital Creativity module running in 2023/24 at Falmouth University

Explore variables including:

- Continuation
- Attainment
- Attitude

If there is interest, a potential multi-national multi-institutional study facilitated using the Runestone ebook platform in 2024/25



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