HUMANIZING THE MACHINE: EMBODIED AND EXPERIENTIAL LEARNING STRATEGIES FOR TEACHING SOFTWARE AND COMPUTATIONAL SUBJECTS

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INTRODUCTION

The rapid expansion of computational disciplines within creative arts education has created two persistent pedagogical challenges: how to teach abstract, symbolic concepts to students whose prior learning might have emphasized materiality and visuality? And how to adapt the pedagogic knowledge and expertise of the institution to disciplines of a wholly novel type? Norwich University of the Arts, with its 180-year tradition of studio-based pedagogy, exemplifies this tension. While the institution has successfully integrated digital courses over the last twenty years, such as computerized animation and textile design, or videogame design, subjects which require the teaching of coding and algorithmic reasoning remain difficult. The introduction of a sandwich year at Level 5 which students from any undergraduate course are able to take has exploded the possibilities for digital creativity within all our disciplines. But it has also highlighted tensions as learners with little or no coding skills enter a year of algorithmic thinking. As Medeiros et al. note, students in general often struggle with "the ability to abstract and generalize" and with "turning a textual problem into a mathematical formula".[1] Concepts such as variables, data types, and memory addresses resist intuitive mapping to real-world objects, creating cognitive barriers which can hold back effective learning. The student programmer "cannot rely only on repetition and memorization. It is necessary to have understanding, problem solving skills, to talk with others".[2]

Conventional strategies such as problem-based learning, live coding, or gamification offer partial solutions but "are still not commonly adopted in higher education.".[3] Norwich's Creative Learning Strategy foregrounds a whole student approach and playful "embodied knowledge,"[4] prompting experimentation with pedagogies that mobilize the body and environment as cognitive resources. This approach is drawn from in-depth consultation with academic staff who are almost universally oriented towards embodied and material thinking irrespective of their disciplines, a philosophy based in post-Bauhaus approaches which is all but hegemonic across Western art and design education. The three case studies discussed below synthesize these innovations with established theory to argue that embodied and experiential learning can transform computational education, especially the understanding of abstract concepts. We also consider implications for inclusivity, particularly for neurodivergent learners.

THEORETICAL FRAMEWORK

Active Learning and Its Challenges

Active learning is widely endorsed in higher education, yet its implementation in computational subjects is fraught with challenges. Some recent studies show that students can feel tense when asked to participate, both by the fact that a lecturer is directly asking them to speak, having to speak in front of the whole class, as well as worrying that they cannot answer a question correctly.[5] If we also consider the after-effects of the COVID-19 pandemic, after which social anxiety disorder peaked generally and more so in students, it becomes apparent that asking student participation without appropriate scaffolding can be dangerous within today's higher education climate. On top of that, the social nature of active learning has “the potential to increase students’ reported anxiety if they fear that others will negatively evaluate them”.[6] This can create a negative cycle in which the student becomes more and more reluctant to participate.

Those students who are more at risk of entering the negative cycle of learning are students with social anxiety and, at the same time, students who have a neurodivergence are more prone to develop social anxiety.

Wlodkowski and Ginsberg’s 1995 framework for culturally responsive teaching offers a lens for designing active learning activities that mitigates these risks.[7] Although Ginsberg and Wlodkowski’s study focused on cultural diversity, their ideas seem relevant to other forms of diversity, as the framework establishes rules to involve students who may be reluctant to participate in class generally. The study proposes that the key points to involving these students are **Establishing Inclusion**, **Developing a Positive Attitude**, **Enhancing Meaning**, and **Engendering Competence**. Each element within the framework has a series of associated norms, which define how it should be reached.

Experiential Learning

Kolb’s experiential learning cycle (concrete experience, reflective observation, abstract conceptualization, active experimentation) provides the implicit framework for day-to-day teaching within creative disciplines.[8] Students typically develop projects through successive cycles of iteration and experiment, responding to materials and feedback from the course community. Papert’s constructionism similarly emphasizes learning through making, arguing that programming environments should enable learners to think with objects.[9] Project-based learning operationalizes these principles by situating knowledge within authentic tasks.[10] When combined with scaffolding and collaborative structures, experiential approaches can accelerate mastery of threshold concepts, those transformative ideas that, once understood, open new disciplinary vistas.[11]

Embodied Learning

Embodied cognition posits that thought is grounded in sensorimotor experience and has gained prominence in discourses of creative education in the last twenty years in relation to tacit knowledge, and concepts such as Schon’s reflection-in-action.[12] Learning is not merely symbolic but enacted through bodily engagement with the environment. It is easy to see how this might apply to subjects such as acting and dance, or even perhaps hand-based skills like ceramics. In computational education, this perspective challenges the dominance of screen-based instruction by advocating for physical modeling of abstract structures. Research in STEM education supports embodied strategies for teaching complex systems,[13] yet their application to creative coding and software training remains underexplored.[14]

CASE STUDIES

1. Sprinting to Success: Project-Based Learning in the Banking Hall

This project operationalized experiential learning at scale, creating excitement through the use of non-standard learning spaces and facilitating access to the university's world-leading research facilities. Guided by the University's Creative Learning Strategy, every course is committed to running a non-curriculum group project, working across years and often adjacent courses, for 1 week every academic year. Projects are typically located in our Bank Plain building, a huge Victorian-era hall which offers the opportunity to configure working spaces in temporary and exciting arrangements. At the time of planning this project, the University had also recently developed an Immersive Visualisation and Simulation Lab (IVSL), with funding from the AHRC. An exciting component of the IVSL is a 10-metre diameter, 4-metre high 360° video screen which the Creative Computing, Technology and Robotics course team were keen to leverage as part of their project.

The project would use the well-known creative coding platform p5.js, created by new media artist Lauren McCarthy in 2013[15] based closely on the earlier Massachusetts Institute of Technology (MIT) Processing framework intended to 'synthesize graphic design with computer science'.[16] Students already had some experience with this platform.

The project would be interactive through the use of MIDI controllers, with 4 controllers on plinths placed in front of each screen quadrant, thus creating an experience that offers physical agency. A pragmatic technical approach was developed, allowing 4 student groups to each work with a laptop outputting a quadrant of the final 360° outcome.

Inspired by project-based learning pedagogy, particularly as it has been applied to STEM subjects e.g. Papert, and Martinez & Stager, the project would create something of value to the learner that also responds to a real-world problem. In such a short space of time and with an aspiration to create high quality project outcomes appropriate to an internationally visible research facility, it would be prudent to incorporate suitable instructional scaffolding. Additional inspiration was derived from the SCRUM project management approach[17] where a 'sprint' is defined as a short, fixed duration period, during which time a team commits to developing a defined outcome based on prioritised requirements, rather than a specific outcome.

Course staff prepared p5.js templates that demonstrated the loading of 4 sets of environmental data – UK solar panel installation 2010-2025,[18] real time UK river flooding,[19] EU Drought Impact,[20] and average global temperature changes since 1880.[21]

Staff and students visited the screen early in the project week to discuss physical implementations and be inspired by existing work. Students were encouraged to research and ideate as a group prior to beginning development, with staff supporting the groups in the exploration and customization of the templates. Subsequently, the 4 LCD screens were arranged in a square to mimic the set-up of the 360 screen. Outcomes were critically appraised by the groups and fine-tuned.

On the final day, staff and students decamped to the 360 screen and installed their work, with additional fine tuning taking place in situ. By 1pm a coding freeze was declared and at 2pm doors opened to colleagues, friends and invited industry professionals.

The creative outcomes demonstrated the success of the project design and execution – the strength of well-scaffolded, well-supported collaborative activity, especially with the incentive of an exciting physical exhibition opportunity. There was a general atmosphere of co-learning, with meaningful co-creation activity that partnered students with both academic and technical staff.

It terms of what might be improved – greater flexibility, e.g., greater student choice of data set, choice of format etc., would be possible if the sprint was held over a longer period. This would align more closely with the original philosophy of Seymour Papert who advocated for greater student choice of project subject as a means to motivate their learning.

Figure 1. Creative Computing, Technology & Robotics project outcomes. Photographs by Andi Sapey, January 2025

2. Find the Duck: Gamified Embodied Coding

In the Find the Duck lecture, students learnt surface-level coding principles by playing with rubber ducks. Year 1 Creative Computing and Robotics students were paired and asked to guide each other towards finding a hidden rubber duck. One student acted as the programmer, knowing where the rubber duck was, and the other as a computer or robot, which had to follow precise instructions to find it. Different iterations of the game were played, in which different rules were introduced to exemplify specific coding principles – for example, in one iteration they had to write all the instructions before "starting" the robot, which meant they had to predict the outcome of their instructions, representing compiled coding. By iterating the game with different rules, students could draw from their prior experiences to predict outcomes and adapt their strategies. Additionally, the playful, hands-on approach encouraged students to explore coding concepts in a low-pressure environment. At the end of the lecture students were gifted the rubber duck they had been working with, thus becoming their new coding companion.

This exercise draws from Active Learning, by getting students into action, and not just presenting coding ideas in a decontextualized manner. The exercise was introduced in a scaffolded manner, by starting with simpler concepts - such as starting with interpreted language, where students could rewrite the instructions as the exercise developed - and moving towards more complex exercises as the lecture advances - such as multithreading, where students had to guide more than one "robot" at the same time.

Furthermore, this lecture was inspired by Wlodkowski and Ginsberg's framework for a culturally diverse classroom,[22] initially geared towards classrooms with cultural diversity. While the original framework was developed in the context of cultural diversity, this particular exercise was developed in a class with high percentage of neurodivergent students as a case study to apply the framework to a different type of diversity. One of the four principles of the framework is to Develop a Positive Attitude towards learning.

With these theories in mind, the lecture aimed to tackle two goals: Firstly, it aimed to make technical concepts more approachable to students who may feel threatened by the technicalities of the language. Secondly, it aimed to promote a positive attitude towards learning among students, by making the learning playful and strengthen horizontal bonds between them.

When the exercises were implemented in class, students that usually seemed quieter seemed to liven up and interact with their peers. Students quickly caught onto the intended playful attitude and reported feeling closer to their peers after the lecture. The concepts presented did not overwhelm students, who grasped everything that was expected of them in that lecture.

3. Embodying Nodal Logic: Teaching VFX Compositing

Learning Nuke, an industry-standard compositing tool used in VFX to manipulate and combine digital imagery, poses a threshold challenge: its node-based, non-linear architecture contrasts sharply with the layer-based logic of software with which many students are typically familiar. To bridge this gap, students enacted the logic physically.

Nuke uses a node-based interface in which users link different operations into sequences known as scripts. Each node can be connected to many others in a non-linear formation. This basic concept involves a degree of spatial reasoning, following chains of logic and non-linear thinking, sharing more in common with visual scripting than most creative software techniques. This is a threshold concept, key to understanding the basic operation of Nuke.

To explore this, students were organized into teams of seven, and each student was given a card representing a function. Each function was a single alteration that could be combined with other functions to create different effects ("I make everything below me red"; "I make a square"). Students were instructed to arrange themselves and their functions into a single line and a specific order to achieve different effects.

Example task: Create a red square

Order of functions: I make everything below me red > I make a square

Result: A red square

The tasks started simply, involving the combination of only two functions, allowing students to feel comfortable and confident with the concept. The tasks then increased in complexity, requiring the students to combine many different functions in specific orders to achieve the desired result. Once they had constructed their sequence, the instructor would call out their functions in order, starting from the bottom and working up, until announcing the final result.

This continued to a point that the students were given a task that was not possible within the limitations of the current system, A big blurry red circle and a small blurry blue square. Though not seemingly significantly different in complexity to the previous task, there is no way for students to successfully arrange their functions in a single line that would achieve the desired result. At this point it was explained to the students that they have been operating a linear, layer-based system (similar to Photoshop which many of them are familiar with). In this linear, layer-based system all functions on the top effect all functions underneath them, creating a fundamental limitation to the system. So the students were challenged to create a new system that would allow them to achieve the result. They very quickly got hold of the idea that they need to create multiple, branching lines.

Order of functions:

I make everything below me blurry

I make everything below me big	I make everything below me small
I make everything below me red	I make everything below me blue
I make a circle	I make a square

Result: A big blurry red circle and a small blurry blue square

At this point it was explained to the students that they were now using a node-based system, allowing for branches of logic and different combinations of functions. From here we explored different, more complex tasks that were now possible within the altered system, before eventually turning to the software itself, with the new understanding of the possibilities inherent in a node-based system.

This approach was based in the idea of experiential embodied learning that uses physical activity and the body's interaction with the environment to enhance learning. By translating the abstract spatial reasoning of the software to physical space, the activity embraced haptic, object-based learning, combining touch sensations and kinesthetic movement to give "continuous contact with reality"[23]. The workshop was designed to embed the ideas more deeply and allow students to physically perform the logic before encountering it onscreen. Outcomes included faster uptake of Nuke and enhanced collaborative problem-solving.

PEDAGOGIC IMPLICATIONS

These cases demonstrate that embodied and experiential strategies can demystify abstract computational concepts by grounding them in physical and social experience. Embodied modelling externalizes invisible structures, making them manipulable and discussable. Gamification and collaborative sprints harness intrinsic motivation, while robust scaffolding in all examples ensured cognitive load remains manageable. Importantly, these approaches resonate with creative arts students' existing dispositions toward materiality and play.

Active learning's social demands risk marginalizing students with anxiety or neurodivergence. As noted above, the social nature of active learning can increase student anxiety and autistic students often face "the cost of success" in navigating higher education.[24] Inclusive design requires anticipatory scaffolding: low-stakes entry points, pair work, and gamified formats that distribute cognitive responsibility. The Find the Duck and Nodal Logic exercises exemplify this by emphasizing collaboration over public performance. Similarly, embodied tasks can support neurodivergent learners by leveraging strengths in spatial reasoning and pattern recognition.[25] Multi-modal activities and embodied strategies in general naturally intersect with universal design for learning (UDL) principles to create genuinely accessible computational curricula.

Challenges and Future Directions

While successful, this type of intervention can be resource-intensive. The Banking Hall sprint demanded significant technical preparation and staff coordination; embodied workshops require space and facilitation expertise which may be present within a creative education environment but cannot be taken for granted across Higher Education more generally. Scaling such practices necessitates institutional commitment and faculty development. Moreover, empirical evidence remains limited. Systematic studies comparing embodied and conventional approaches on learning outcomes, retention, and affective measures are needed and would be a logical next step.

Conclusion

Teaching computational subjects in creative education contexts demands pedagogies attuned to the embodied nature of cognition and the experiential basis of understanding. By mobilizing physical activity, collaborative making, and authentic performance, educators can render abstract concepts tangible, foster inclusion, and cultivate resilience in learners navigating challenging threshold concepts. The examples presented here affirm the potential of embodied and experiential strategies to humanize the machine; transforming code from an opaque syntax into a lived, shared practice. As a university, we plan to consolidate these innovations into scalable models, evaluate their impact, and theorize their implications for the evolving landscape of computational literacy in our historic artistic context.

NOTES

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