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INNOVATIONS IN THE DESIGN OF AN ARCHITECTURAL ENGINEERING CURRICULUM

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ABSTRACT
This paper introduces a new curriculum, launched in October 2021, in Architectural Engineering, designed out of London, UK for implementation in Giza, Egypt. The developers of this newly formed higher education institution, Newgiza University, sought to introduce more contemporary approaches as well as cutting-edge curricular innovations to the education landscape in Egypt. To achieve this, they enlisted curriculum developers in architecture and engineering from University College London who have expertise in education research, curricular innovation, and the delivery of engineering and architecture modules and degree programs. The team worked in collaboration with experts and educators from Egypt to create a bespoke curriculum, drawing from a range of innovative approaches and educational theories, combining these with many well-established approaches. This paper, which represents the "scholarship of integration", highlights distinctive aspects of the curriculum, and illustrates how prior research was integrated into the curriculum design, with a focus on the first year. The paper is geared toward design educators as well as curriculum developers.

Keywords: Curriculum design, interdisciplinary, scenarios, challenges

1 INTRODUCTION
In keeping with the theme of the 2022 conference on Engineering and Product Design Education, we aim to "Disrupt, Innovate, Regenerate and Transform" in the design of a new degree course in Architectural Engineering (AE) for Newgiza University (NGU) located in Giza, on the outskirts of Cairo, Egypt. The new AE curriculum brings architecture, building design, art, planning and business together with engineering. We draw together the best of engineering and architecture education pedagogy and practice, and incorporate novel components developed and tested at University College London (UCL), as part of the Integrated Engineering Programme (IEP) there [1] and reported as ground-breaking in reports published by MIT [2, 3].
AE is one of a suite of degree courses that UCL Consultants have designed for implementation at NGU. Medical degree programs (i.e., Medicine, Dentistry and Pharmacology) were previously designed for NGU and are up and running. In October 2021, NGU launched its first two engineering programs – one in AE and the other in Computers, Communication and Autonomous Systems (CCAS). The design of all these draws from UCL research on learning and teaching and principles of an "integrated curriculum" as defined by Fung [4].
Here, we describe our integrated approach to the development of architectural engineering professionals. Fundamental topics are not taught separately but integrated into applied engineering topics and synthesized with the theoretical and practical architecture-based modules. This integrated approach bolsters the students' understanding of various artistic and fluid architectural methodologies. After discussing distinctive qualities of the AE curriculum, the paper provides an overview of the first-year AE studio syllabus and identified theories that underpin its design.

2 DISTINCTIVE QUALITIES OF THE AE CURRICULUM
We have set out to inspire design innovation, aiming to equip students to develop creative, poetic, novel and artistic visions and approaches to the more experimental and technically rigorous elements which sit within the structural, mathematical, technological, and engineering aspects of the degree. We want to produce well-rounded, future-oriented, creative architects equipped with know-how that draws

together the artistic creativity of architecture, combined with technical and digital skills of other engineering disciplines, to help forge a better living environment for clients, communities, and the world at large. We also want to infuse architectural practice in this region with rich Egyptian history, and artistic and cultural influences of past and present Islamic and Arab civilisations. We integrate global themes in artificial intelligence, sustainability, and climate change.

2.1 Vertical threads

The AE curriculum design has threads that run vertically through the years to support and link core technical, theoretical, and practical modules. These vertical threads are shared, and taken by all students, within NGU Engineering: (a) Arts, History, Culture and Society (AHCS); (b) (c) Business, Management and Entrepreneurship; and (c) Professional Skills. AHCS draws from the local context and Egypt's proud heritage in architecture, technology, and knowledge production. Further complementing the first year AHCS module taken by all AE and CCAS students, Egyptian history features prominently in the primary textbook [5] for the first year, first semester "condensed" design studio (see Section 3 below).

2.2 Challenges and Scenarios

Students are challenged to develop their theoretical knowledge, engage with experiential learning, and simultaneously put that knowledge into practice, while developing professional skills and exploring their own creativity and design practice, through a series of projects (termed 'Challenges' and 'Scenarios'). These projects add another dimension to the studio-based study and practice of the AE program, as they are interdisciplinary (i.e., Challenges are shared project modules with students from the CCAS program) and time-intensive (i.e., Scenarios are 1- to 2-week long intensive projects that focus on discipline-specific content which allow student teams to go deeper in their understanding and practices of core technical and learning outcomes). These authentic and industry- or community-inspired and supported activities help students connect their learning and practice to the techniques and skills that will be critical for their future professional success.

In the first semester of first year, all NGU Engineering students undertake a sustainability and quality of life Challenge project in interdisciplinary teams. In the second semester, students experience two one-week long Scenarios scheduled approximately seven weeks apart. Halfway through the semester, all classes are paused for the students' first Scenario experience called "Pebble in the Pond" focused on applying physics-based concepts and calculations, creating a Rube Goldberg type machine to move a pebble and deposit it into a "pond", discussing the rippling effect of an engineer/architect's actions, and analysing an ethics-related case study. The semester culminates with a second week-long AE specific Scenario to introduce students to the architectural charette and competition formats, challenge them to develop new graphic communications and media skills in the design of a linear trellis for a site they previously diagrammed. The focus here is on the site context, sustainability, user needs, and consideration for mitigating risks.

2.3 Teamwork and other student-centred learning approaches

Teamwork is central to engineering education, where students are prepared for global, transnational work and design is seen as a group effort enriched by diverse perspectives. This stands in contrast to the traditional view of architects as lone figures—design geniuses and "starchitects" working in isolation to craft the perfect/utopian design. This new AE curriculum draws from the blossoming field of "engineering education research" and innovative engineering education practice and includes a focus on team-based design skills. It integrates engineering problem-solving and teamwork [6] approaches with more artistic and poetic aesthetic practices typically celebrated in architectural education. It also draws from a litany of research on student-centred learning, such as phenomenographic research by Barrie [7] who identified six different categories of concept held by university-level educators about where and how students would develop transversal skills or "graduate attributes" like communication, teamwork, and time management. In the AE program, a balance is struck between implicitly developing such skills because of the inherent structure of the curriculum and consciously and purposefully integrating assignments that would build these skills into the modules whilst helping to create a holistic campus environment where students learned to connect and integrate across various types of formal and informal learning experiences.

2.4 Trans-disciplinarity

In addition to connecting the AE and CCAS curricula in every academic year via shared modules and providing interdisciplinary design projects (as detailed above), trans-disciplinarity enhances the uniqueness of our program. Over time, NGU will expand its offerings to include other fields of engineering and will provide increasingly trans-disciplinary integrated design opportunities via Challenges and Scenarios, because students will work in project teams with more and more engineering and architecture fields represented. Regarding trans-disciplinarity, the AE program has been designed to include four graduate pathways, one of which aligns with the CCAS curriculum whereby AE students will specialize in technologies for smart building design through the learning of programming, integrated sensory system design and IOT. AE students also encounter trans-disciplinarity in their first year, where the introductory design studio has been condensed to make space for engineering-related coursework (e.g., calculus and physics) to a higher level than expected in a standard architecture-only curriculum, and because NGU have requested options for students to switch streams during their first year.

3 AN OVERVIEW OF THE FIRST-YEAR STUDIO CURRICULUM

The first-semester's condensed AE studio includes reading and discussion of basic design fundamentals and gives students a chance to apply these in practice via abbreviated design activities focused on developing specific technical skills and applying simple design concepts. The student has one hour to discuss the readings, guided by the teacher presenting images to supplement the textbook [5], and another four hours wherein techniques are demonstrated and then applied in design exercises. Between formal sessions, students are expected to read and to spend nine additional hours developing their designs. Due to the condensed format, the exercises are straightforward and are drawn from established sources [e.g., 8].

The second semester studio is more highly customized and involves four projects. The components of Project 1 are named: **Transverse** (learn about buildings by drawing sections); **Travel** (learn to diagram experience); **Wrap** (analyse and deconstruct an item one wears). Project 2 comprises: **Colour** (study how colour works and make colours); **Fold** (learn to create space by cutting and folding paper geometrically); **Light** (learn to modulate light by designing a light fixture). Project 3 involves: **Stepped** (study carved spaces geometrically); **Water** (demonstrate the physical and phenomenological properties of water to others); **Labyrinth** (create a sequence of cavernous spaces that reveal the essence of water to others). Project 4 involves a digital portfolio where students reflect, document, and present their learning journey.

3.1 Digital portfolio of learning journey

In the first-semester AE studio, students curate a digital repository of their design work as well as reflective essays that use the Gibbs model of reflective practice [9]. In the second semester students extend their repositories, drawing from them to develop digital portfolios to showcase their work and their development as a learner and designer, and to explain how they have met the learning objectives of the course and of the various projects.

4 UNDERPINNING THEORIES

Lessons from the first semester textbook [5] are recalled and discussed again during the second semester, where students are also asked to purchase practical guides, and provided with a list of recommended modernist texts. Students are assigned a reading on phenomenology and their teachers read articles on Egyptian daylighting strategies, design theory, and learning strategies.

4.1 Informed Design Matrix

A cornerstone of the beginning design curriculum (i.e., the first two years of architect studio learning) is the "the informed design teaching and learning matrix" [10]. The matrix, developed using the scholarship of integration with an extensive literature review, identifies patterns that distinguish naïve design from more informed design practices. Part of the matrix is provided in Table 1. The full matrix suggests how to build informed practices among students. In the full version, each pattern is paired with a list of suggested learning goals and teaching strategies.

Table 1. The Informed Design Teaching and Learning Matrix [10, p. 738-797]

Design Strategies	**Beginning vs. Informed Designer Patterns**	
	WHAT BEGINNING DESIGNERS DO	**WHAT INFORMED DESIGNERS DO**
Understand the Challenge	***Pattern A: Problem Solving vs. Problem Framing***	
	Treat design tasks as a well-defined, straightforward problem that they prematurely attempt to solve.	Delay making design decisions in order to explore, comprehend and frame the problem.
Build Knowledge	***Pattern B: Skipping vs. Doing Research***	
	Skip doing research and instead pose or build solutions immediately.	Do investigations and research to learn about the problem, how the system works, relevant cases, and prior solutions.
Generate Ideas	***Pattern C: Idea Scarcity vs. Idea Fluency***	
	Work with few or just one idea which they can get fixated or stuck on and may not want to change or discard.	Practice idea fluency in order to work with lots of ideas by doing divergent thinking, brainstorming, etc.
Represent Ideas	***Pattern D: Surface vs. Deep Drawing and Modelling***	
	Propose superficial ideas that do not support deep inquiry of a system, and that would not work if built.	Use multiple representations to explore and investigate design ideas and support deeper inquiry into how systems work.
Weigh Options and Make Decisions	***Pattern E: Ignore vs. Balance Benefits and Trade-offs***	
	Make design decisions without weighing all options, or attend only to pros of favoured ideas, and cons of lesser approaches.	Use words and graphics to display and weigh both benefits and trade-offs of all ideas before picking a design.
Conduct Experiments	***Pattern F: Confounded vs. Valid Tests and Experiments***	
	Do few or no tests on proto-types or run confounded test by changing multiple variables in a single experiment.	Conduct valid experiments to learn about materials, key design variables and the system work.
Troubleshoot	***Pattern G: Unfocused vs. Diagnostic Troubleshooting***	
	Use an unfocused, non-analytical way to view prototypes during testing and troubleshooting of ideas.	Focus attention on problematic areas and subsystems when troubleshooting devices and proposing ways to fix them.
Revise/ Iterate	***Pattern H: Haphazard or Linear vs. Managed and Iterative Designing***	
	Design in haphazard ways where little learning gets done or do design steps once in linear order.	Do design in a managed way, where ideas are improved iteratively via feedback, and strategies are used multiple times as needed, in any order.
Reflection Process	***Pattern I: Non-Reflective vs. Reflective Thinking***	
	Do tacit designing with little self-monitoring while working or reflecting on the process and product when done.	Practice reflective thinking by keeping tabs on design strategies and thinking while working and after finished.

Pattern A, for instance, "Understanding the Challenge" can be developed via learning goals where students (a) **define** criteria and constraints of challenge and (b) **delay** decisions until critical elements of challenge are grasped and with teaching strategies that have students (c) **state** criteria and constraints from design brief in one's own words; (d) **describe** how preferred design solution should function and behave; and (e) **reframe** understanding of problem based on investigative solutions [quoted from 10].

4.2 Theories on student learning and development

In addition to explicitly discussing informed design patterns with students across the first and second years of design studio, we also present many architectural and design precedents and deliver, during the studios, presentations on technical aspects (such as laser cutting, 3D printing, and graphic design software). Each semester, we provide lectures, via the design studio, on various aspects of learning, including Kolb's learning cycle and experiential learning model [11], strategies for test-taking [12], and Dewck's theory on growth mindset [13] and integrating research on how the theory is used in engineering [14]. We also draw from Sanford's theory of challenge and support [15], Astin's theory of student engagement [16], and theories related to how students develop intellectual, moral, and ethical [e.g., 17], and reflective judgement [18].

4.3 Research on feedback and assessment

We respond to published critiques of the studio format and the jury format for assessment [19, 20] in our design for feedback and assessment [that draws from 21]. We developed assessment rubrics to be used formatively (while the students are in the process of developing their designs) as well as summatively (at the end of the project and the semester).

We aim to provide written and verbal feedback to students at least once during each project sequence, preferably at a formative stage when they can directly act upon the advice and integrate it into their work. For formative feedback, we recommend using ***Closed Juries & Open Feedback*** with assessment as a reflective tool. In this format, upon submission of students' work, it is reviewed by tutors in private. Then grades as well as written feedback are provided to the students. Students are expected to reflect on the feedback given before meeting with their tutor privately to discuss it [21, 22, 23].

In the second-semester design studio, summative assessment happens at the end of each project when students are given their first opportunities to present verbally in a formal setting. For this, UCL has suggested to try the ***'Red Dot' Review*** format (or ***Gallery Review***) [developed by 22, drawing from 23, 24]. This review format involves inviting guests, faculty members, and students to place one red dot (or, similarly, up to three sticky notes) on exhibited projects they wish to hear presented. Based on the number of red dots/votes received, a limited number of student projects is selected for presentation. The spirit of this presentation is celebratory, and the discussion which ensues includes conversation among the students. During the primary exhibition phase, students may have the opportunity to discuss their work in small groups, where experts, faculty members, and students mill around and discuss the work in a somewhat casual way. The teacher also makes a holistic end-of-semester assessment of each student's readiness to progress into the subsequent studio.

5 CONCLUDING REMARKS

An overview of the innovative curriculum design of an Architectural Engineering program purposefully built for implementation at a new higher education institution in Egypt is presented in this paper. It enlists a "scholarship of integration" approach aimed at embedding: vertical threads of contemporary learning through all years of study; student-centred team-based learning through a variety of design project opportunities in the form of Challenges and Scenarios alongside the architecture studios; and trans-disciplinary learning opportunities alongside other engineering students within the school. The details provided of the first-year studio curriculum give insights into its atypical approach, whereby the introductory semester studio is designed as a heavily guided and structured student learning experience leading into a much more student-driven final semester studio customized through a set of interrelated projects. Finally, the richness and diversity of the educational theories underpinning the detailed design of the first-year studios support and help manifest our interpretation of the Crismond and Adams "informed design teaching and learning matrix" aimed at moving students from naïve designers to designers with more informed practices during their years studying at NGU.

REFERENCES

[1] Mitchell J. E., Nyamapfene A., Roach K. and Tilley E. (2021). Faculty wide curriculum reform: the integrated engineering programme. *European J. of Engineering Education, 46*(1), 48-66.

[2] Graham R., Crawley E. and Mendelsohn B. R. (2009). Engineering leadership education: A snapshot review of international good practice. *White paper sponsored by the Bernard M. Gordon-MIT Engineering Leadership program*.

[3] Graham R. (2018). The global state of the art in engineering education. *Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA*.

[4] Fung D. (2017). *A connected curriculum for higher education* (p. 182). UCL Press.

[5] Ching F. D. and Eckler J. F. (2013). Introduction to architecture. John Wiley & Sons.

[6] Helmi S. A., Mohd-Yusof K. and Phang F. A. (2016). Enhancement of Team-based Problem-Solving Skills in Engineering Students through Cooperative Problem-based Learning. *International Journal of Engineering Education 32*(6), 2401-2414.

[7] Barrie S. C. (2007). A conceptual framework for the teaching and learning of generic graduate attributes. *Studies in higher education, 32*(4), 439-458.

[8] Friedman J. B. (2000). *Creation in Space: Fundamentals of Architecture, Volumes 1 and 2*. Kendall/Hunt.

[9] Gibbs G. (1988). *Learning by doing: A guide to teaching and learning methods*. London: Further Education Unit.
[10] Crismond D. P. and Adams R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education 101*(4), 738-797.
[11] Kolb D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.
[12] Kitsantas A. (2002). Test preparation and performance: A self-regulatory analysis. *The journal of experimental education*, *70*(2), 101-113.
[13] Dweck C. (2017). *Mindset-updated edition: Changing the way you think to fulfil your potential*. Hachette UK.
[14] Campbell A. L., Direito I. and Mokhithi M. (2021). Developing growth mindsets in engineering students: a systematic literature review of interventions. *European Journal of Engineering Education*, *46*(4), 503-527.
[15] Sanford N. E. (1962). *The American college: A psychological and social interpretation of the higher learning*.
[16] Astin A. W. (1997). *What matters in college?* JosseyBass.
[17] Perry Jr W. G. (1999). *Forms of Intellectual and Ethical Development in the College Years: A Scheme. Jossey-Bass Higher and Adult Education Series*. San Francisco: Jossey-Bass.
[18] King P. M. and Kitchener K. S. (1994). *Developing Reflective Judgment: Understanding and Promoting Intellectual Growth and Critical Thinking in Adolescents and Adults.* Jossey-Bass.
[19] Boyer E. L. and Mitgang L. D. (1996). *Building Community: A New Future for Architecture Education and Practice*. *A Special Report*. California Princeton Fulfillment Services; Ewing, NJ.
[20] Anthony K. H. (2012). Studio culture and student life: a world of its own. MIT Press.
[21] Flynn P. (n.d.). Testing the New Model for Feedback. Whitepaper form the project "*Rethinking the Crit: A new pedagogy in architectural education*". Technological University Dublin.
[22] Cameron M. (2014) The Jury's Out: A Critique of the Design Review in Architectural Education, University of Canberra.
[23] Anthony K. H. (1991). Design juries on trial. London: Van Nostrand Reinhold.
[24] Sara R. and Parnell R. (2013). Fear and learning in the architectural crit. *Field Journal*, *5*(1), 101-125.