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THEORISING A NEW EDUCATIONAL AGENDA FOR SUSTAINABLE BUILT ENVIRONMENT PROFESSIONALS: TIMBER TECHNOLOGY, ENGINEERING, AND DESIGN PROGRAMME

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ABSTRACT: (200) The paper reports on the most recent activities undertaken on the local and national levels to create a competency framework for timber engineering in an effort to change the traditional construction methods into more sustainable and environment friendly methods based on the use of biogenic materials. The paper further details the various pilot projects and educational programme developed to upskill professionals of the built environment. More details are provided on the capstone educational programme including its structure, strategy, delivery and content.

KEYWORDS: Timber Design Education, Sustainability, Architecture

1 INTRODUCTION

The construction sector, including building materials, is at the centre of a climate change and global warming since it represents 33% of global final energy use, generates nearly 40% of global energy-related Green House Gases emissions and consumes 40% of global raw materials [1]. In the UK, Co_2 emissions from construction industry reached 13.5 million metric tons in 2019 [2]. The direct cause for emissions might be the elements mentioned above, but in reality, there is an underlying cause which contributes and converges to form the results above. One might argue that the main contributors are lack of research into sustainable building materials, the education which is not based on sustainability, and the economic drivers that favours financially short-term cost-effective measures over long-term sustainability.

The desire to use sustainable materials needs to be coupled with active research into sustainable biogenic materials that effectively competes with the currently available non-sustainable traditional construction materials.

On the other hand, the formative educational outputs from higher education institutions and training centres around the globe revolve around old and traditional knowledge that has the economic costing feasibility at its centre, whereas sustainability and environmental friendly materials come as an afterthought when compared to project design, construction and economic costing considerations.

Moreover, the current practices in-place within the construction industry are direct responses to the market demand which sees construction and built environment professionals under-trained and ill-equipped with the knowledge to tackle sustainability considerations for two reasons: a) they do not have the knowledge required for sustainable construction, and b) the context in terms of practices and materials does not necessarily aid the endeavour to achieve sustainability. In other words, a construction manager, or an architect, or even an architectural technologist will not necessarily have the experience of running sustainable projects, and their knowledge of designing, detailing or running projects includes traditional materials that are not necessarily sustainable.

Triple factors above; namely practice, education, and knowledge are not up to date with sustainable options. Each of the factors need to be addressed on a global scale. The paper and its outcome describe an attempt on a national scale in the UK to address the issue by proposing a new triple helix action to address the emergency. Our efforts and reaction are demonstrated using Biogenic materials as an example of sustainable construction materials, and in specific, we are using timber as an

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example of such sustainable materials. So, what follows will be addressing timber.

It is evident that the sector's contribution is an issue that requires addressing. This paper reports on the unique approach developed and implemented by the Centre for Advanced Timber Technology within The New Model Institute for Technology and Engineering that predicates over multiple axioms linking professionals of the built environment, operations in construction industry and its supply chain, and finally materials used in construction. Through this multiple approach, analysis is carried out in the sector to outline a new agenda for sustainable built environment education that redefine the built environment professional, equips him/her with new knowledge, skills and tools to address the climate crisis through net zero carbon design, and finally offers alternative sustainable construction materials (biogenic) with specific focus on Timber as an example. This forms our future action triple helix of research into sustainable materials, education of sustainability in construction using sustainable materials, and finally informing the new standards of professional practice that is based on sustainable education and sustainable materials.

2 THE COMPETENCY FRAMEWORK

The first step in creating an agenda, is understand the professional practice environment, which in turn requires a survey that covers the construction and built environment needs as derived from various professional roles within it. To be able to conduct such survey and link it to all levels of the problem on the one hand, and feed it to all levels of solution, on the other, it is important to have an overarching strategy that regulates the relationship between different elements and parties. The development of such strategy was the first step in our endeavour, and the outcome, (figure 1), and identifies the delivery partners (namely NMITE, Edinburgh Napier University and Timber Development UK) and the steering group committee which consists of various key players in the market.

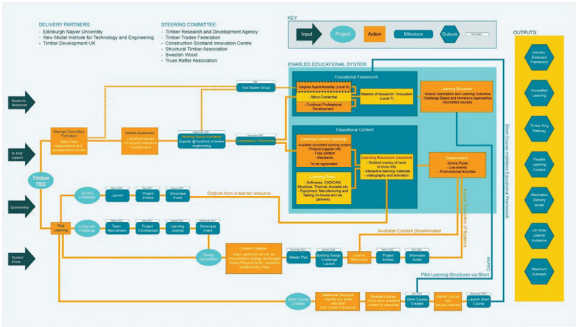

Figure 1: *The overarching strategy*

The strategy identifies areas of investigation that links the market assessment, and the resulting working group, to market needs leading to a series of projects, actions and outputs. From the outset, the educational output was a major key player in that it required a survey of requirements, and a framework that regulates the knowledge to help identify the gap.

The result is an educational framework that acts as a guide to any trail-blazer group that reacts to the requirements above. The reactions required were in the form of continuing professional development short courses, undergraduate and postgraduate degrees. The content of the degrees will respond to the market assessment which included analysis of roles and duties of each built environment profession, and assessment of the knowledge gap.

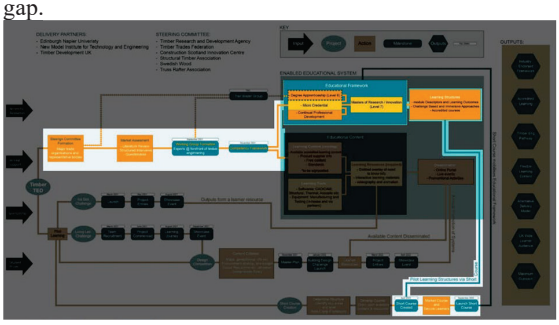

Figure 2: *Development process*

Figure 2 above highlights the educational process stemming from the strategy. It progresses from the survey of the market needs into the development of an educational framework that outlines the content and type of knowledge required for the educational intervention. What follows below is a description of the process of developing the educational framework.

2.1 FRAMEWORK DEVELOPMENT

The competency framework is developed to document the knowledge, meta skills, and industry experience the next generation of timber professionals in construction need in order to drive the change in the construction industry towards biogenic offsite manufacture.

Figure 3: *Steps to be taken produce a feamwork*

The process starts by analysing available resources to the project in the form of logistics, then establishing action frameworks for each individual component listed in figure 3, and then moving to an interview phase where key stakeholders were asked to share their reflections and views in order to draw the themes that frame the intended outcome. Several revisions saw the final framework through. The process also saw the creation of a working group of different contributing parties and a steering group to oversee the implementation.

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2.2 COMPETENCIES

The competency framework sought to answer the question of what are the competencies underpinned in the practice for sustainable construction and therefore education? To which, the answer came from the surveys and partners and after an extensive analysis of different built environment roles in contrast with activities and processes linked to sustainable practices taking timber as the main construction material. The result was divided into two categories: core technical competencies (figure 4), and cross-disciplinary competencies (figure 5).

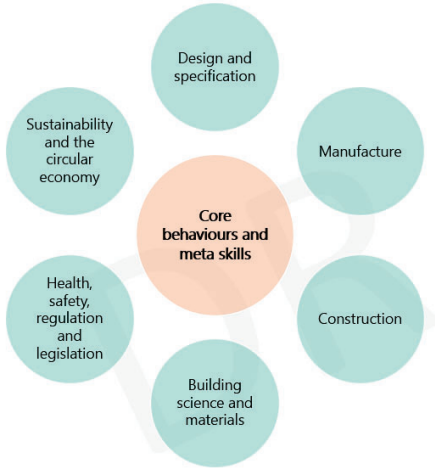

Figure 4: *Core technical competencies*

The former cover aspects like sustainability, manufacture, health and safety, construction, building science, and design and specification, while the latter include the topics of communication, business and commercial, quality, management and digital data.

Figure 5: *Cross-disciplinary competencies*

At the heart of the cross disciplinary competencies, we have certain core behaviours and meta skills (table 1), that revolve around qualities like teamwork, critical thinking, innovation, organisation, professionalism, and ethics.

Table 1: *Core behaviours and meta skills*

Behaviour
Collaboration and teamwork
Critical thinking and problem solving
Innovation
Organisation
Professionalism and career development
Ethics

Each of the competencies contain several knowledge topics, which will be tested in several learning experiences or activities in order to ensure its effectivity in addressing the challenge that is the climate emergency. In what follows, we will have a brief description of learning experiences.

3 PILOT LEARNING EXPERIENCES

The learning experiences suggested predicate on three axioms:

a) the concept of deconstructing existing professional knowledge and its method of attainment into various constituting components and then augmenting the knowledge with our competencies, with the focus being on the technical competences.

b) the action of gauging existing learning styles in the market, with the professional reception of activities being a measure of success through demonstrated demand, and

c) the multiplicity of pedagogic approaches utilised and demonstrated in the learning experiences act as a method of assessment for the efficacy of the approaches.

The learning experiences are described in what follows.

3.1 SUSTAINABILITY ENRICHMENT WEEK

The Sustainability Enrichment Week is series of events involving postgraduate university students within the field of the sustainability in the built environment, who will assemble at our living lab centre in Hereford to engage in several activities, such as workshops focusing on topics like sustainability in construction, environmental ethics, or organisational change management; field trips; and seminars. This is treated as an opportunity to assess their existing knowledge of the topic and find out any potential gaps in this knowledge in order to allow us to trial different techniques to top up the knowledge and experience and take it into the level required by the competency framework. While the participating students are at university level, the intention is to have learners from different parts of the built environment sector. The choice of sample for this activity (postgraduate students) reflects the midpoint in the spectrum of professionals in the field which has undergraduate students on one end of the spectrum, and experienced professionals on the other end. Within the spectrum postgraduate students tend to have the underpinning experience in addition to some professional experience.

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3.2 ICE BOX CHALLENGE

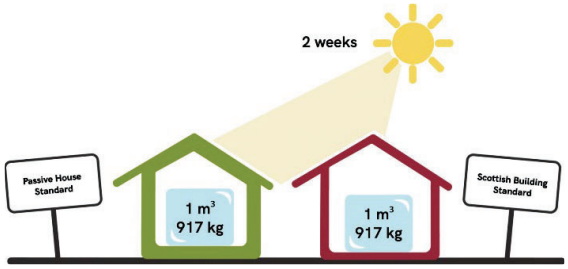

Figure 6: *Ice Box Challenge concept*

The Ice Box Challenge was presented as part of the COP26 event held in Glasgow. The learning experience is designed to allow participants to interrogate existing energy-efficiency building design standards and codes when it comes to sustainability within the built environment. This is carried out through showcasing the potential of an energy-efficient, Passivehaus standard design against a Scottish building standard design.
Two groups are tasked with designing, manufacturing and building two different box structures and applying the insulation as coded by the two different standards. Not only did the outcome favour the Passivehaus standards, but the two structures which were designed, manufactured and assembled, are acting as demonstration for both critical and comparative thinking all while allowing learners the opportunity to examine the result of applying the codes into practice.

Figure 7: *Actual ice boxes designed and manufactured by participants.*

The two boxes have been shipped to Hereford and will be used to carry out further research and as a learning tool for students to learn about thermal efficiency and to be used as a model to learn about manufacture software.

3.3 TDUK DESIGN COMPETITION

TDUK, in association with the Passivehaus Trust, NMITE, and ENU, have launched a university design challenge for built environment students and 2021 graduates from across the UK.
The design competition is learning experience based on forming groups of built environment students to undergo a Passivehaus design in reaction to a real design brief. The group of students need to design and make all the calculations to ensure their work is a NetZero design, or even negative. In its most recent iteration, the aim of the competition is to design a new building to be built in Hereford that will serve as a sports, food, and skills community focal point for the people of South Wye, UK. As part of the programme, students had the chance to learn from webinar series hosting several experts of the sector. The pedagogic approach behind the learning experience is to allow graduating students to have first-hand experience of working on a project with a real targets. This is one of the cases where work-place challenge is proposed to participants with the outcome to be built. The groups are supported with design and production software and tutoring sessions to guide their design.

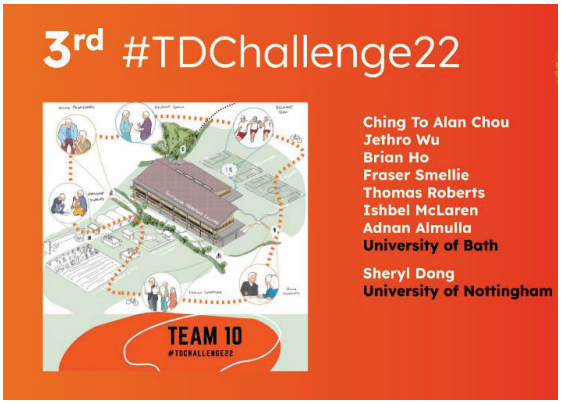

Figure 8: *The winning entry and team members' names and affiliations*

4 THE PROGRAMME

4.1 TIMBER TED SHORT COURSES

The Timber Technology, Engineering, and Design (Timber TED) short courses create comprehensive and flexible upskilling and reskilling training on modern methods of timber construction. Micro-credentials approach is utilised to aid learners in gaining specialist timber construction knowledge and skills for built environment 'better, faster and greener' delivery, addressing the climate emergency and affordable housing crisis. Underpinned by the competency framework described in section 2, identifying the evidence-based technical knowledge and meta-skills required, the short courses are grounded in immersive 'learning by doing' activities, stimulating critical thinking and instilling new knowledge and skills for net zero carbon.
The courses are also based on all of the previously trialled learning experiences, and that leads up to the main experience which is embedded in (Timber TED) series. Combining various competencies from the framework to compile short 12-week courses with different learning and teaching strategies, embeds resilience into the content and delivery mode of the course. All courses are based on workplace challenges that sees students take on activities that mimic their workplace activities and apply different areas of knowledge and application to create learning outcomes (figure 9).

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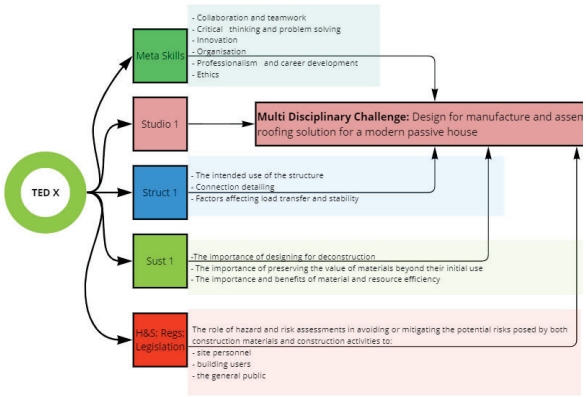

Figure 9: *Example of different areas of knowledge and areas of application compiled to form learning outcomes.*

Once areas of knowledge are compiled, the themes of the TED short course are decided and are ready for development. The diagrams in figure 10 and figure 11 show TED1 and TED2 themes respectively. It is worth noting that the Design and specifications demonstrated in Figure 4 is translated into 'studio' element in the figures below as in our view, the studio element is the place where learners have the chance to design and apply the technical knowledge they attain other modules. This is a crucial element as it prepares the learners to experiment and make mistakes as opposed to learning only how to repeat ready-made of the shelf solutions.

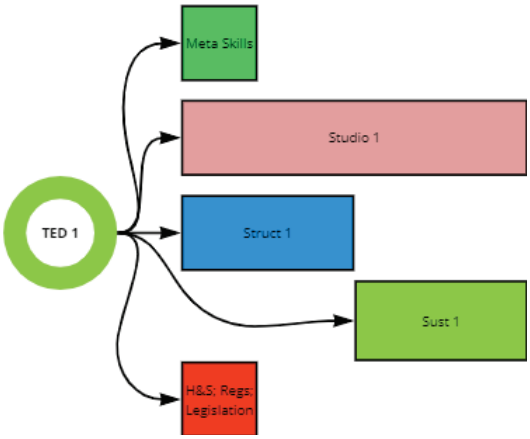

Figure 10: *Different thematic technical competencies are mixed with cross disciplinary skills to form TED1*

TED 2 in figure 11 shows yet another different themes in the technical competencies, namely 'construction' and 'technology'. Both areas are applied in the studio element to allow learners to put their gained knowledge to test.

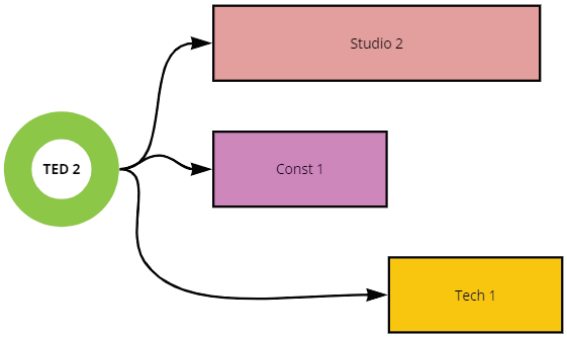

Figure 21: *Different thematic technical competencies are mixed with cross disciplinary skills to form TED2*

The main *aim* of Timber Technology, Engineering and Design (Timber TED) courses is to cover the 'core technical competencies' in the framework (figure 4). From now, on, we will be using Timber TED1 as a subset and an example.

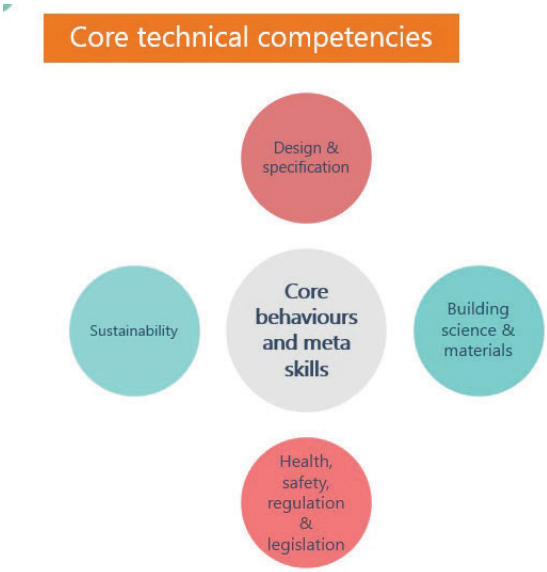

Figure 32: *TED1 core technical competencies*

In the figure 12, competencies are derived from the Timber competency framework which was developed based on a market survey involving Timber engineering and design stakeholders. In addition, an extra layer that covers the 'cross-disciplinary competencies' is introduced to each element of the technical competencies. The three areas covered are: a) Timber Design, b) Timber Material Science, and c) Sustainability. The way they are lined up is visually demonstrated in the diagram below where the first part of the 'Design' module runs concurrently with the 'Materials' module for six weeks. The second part of the 'Design' module runs concurrently with the 'Sustainability' module for the following six weeks. The total is 12 weeks. During the twelve weeks, learners will have residential weeks in the first, sixth and twelfth week

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at our campus in Skylon Park. The rest of the activities are delivered online.

4.1.1 Teaching and Learning Environment

The teaching and learning environment of Timber TED1 is divided into real environment and virtual environment. The latter is hosted on our VLE, whereas the former is divided into 3 major parts: a) the CATT building in Skylon Park, b) workplace environment of our course learners, and finally c) the selected locations that the course will drive learners to in the form of fieldtrips.

4.1.2 Teaching and Learning Strategy

The strategy is, therefore, divided into various techniques and methods, but all revolve around NMITE ethos and principles of learning by doing, and utilising workplace challenges as a method to achieve hands-on experience.

The 'Material Science' module is delivered online with some interactive elements that are examined on campus. Learners are required to review the resources provided online (read, listen, watch and sometime answer questions to frame their gained knowledge. Learners are also invited to obtain sample timber pieces during their first week on campus, and to take it back with them to their homes and keep it exposed to their local weather conditions for twelve weeks and bring it back during their last residential week in order to allow all to have a look at the weathering effect on each sample from different geographic location. During their first residential week, learners are taken in a field trip to a forest, sawmill and an under-construction timber building. This is to take them through the different stages of timber lifecycle.

The direct interaction with the expediated timeline lends itself to the metaphor of time-travel, where learners meet the experts in each field and watch a synoptic 'time-slice' of the intended lifecycle.

Similarly, the 'Timber Design' part of the course is delivered partially online. The main metaphor behind the delivery of the module is to mimic the professional environment in firms. Learners from different professional backgrounds and career paths engage in the following activities:

a) Week 1 begins by revealing the first design challenge they need to respond to. They are presented with a design brief asking them to individually carry out a design and build exercise (design a timber joint). From that point they are taken through a journey of learning:

b) Sketch design exercise where they express their initial raw ideas and demonstrate their current level of knowledge and skills. It also allows the tutors to supervise the activity and provide guidance on how to brain storm concepts and sometimes contradicting demands to reach an outcome in a short space of time.

c) Week 2 presents another challenge where learners are tasked with producing a technical report. Again the idea is to present the knowledge gained in Material Science module about timber and deploy it in the Timber Design module to justify their choice of timber that they are going to use in their design and build exercise. Writing the report also mimics professional activities in the workplace and can be produced within each learner's work environment. Learners will also present further sketches/technical drawings of their idea to demonstrate the research and development work they carried out.

d) Week 3 sees learners delivering their CAD drawings to finalise their ideas.

e) Week 4 is the first chance for learners to discuss manufacture techniques. They consult the learning facilitators to find out what working drawings they need to produce and what activities and tools they will consider in the process of manufacture. The advantage of this activity is that it ties together the information gained in weeks one and the work that will be carried out in week 6

f) Week 5 will be reserved for presentation work.

g) Week 6 will see learners arrive on campus and use our facilities in the CATT workshop to:

I. Produce their design. This is a hands-on exercise where they work under the supervision of the learning facilitator, to produce their design using manual carpenter's tools.

II. Present their work to a critique panel and their colleagues and answer questions

Week 7 to 12 will run a similar design and build activity with two major distinctions:

- The design project will increase in complexity.
- The learners will be divided into groups.

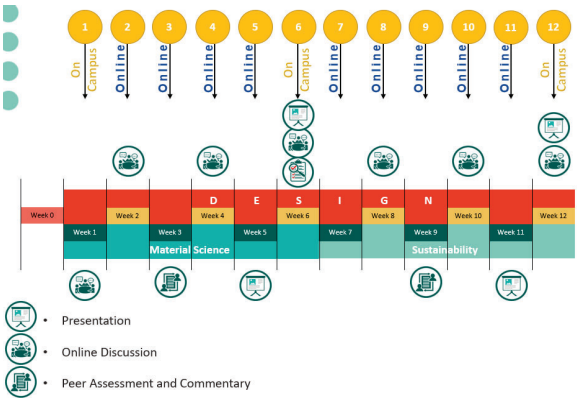

Figure 43: *Distribution of different activities over the period of 12 weeks.*

The second design brief is a group work exercise. Learners bring all their backgrounds and experiences and work together to design and build a relatively complex outdoor structure. They navigate group-work dynamics to achieve their target. They replicate the steps in weeks 1 to 6 and they produce a group technical report, group drawings presentation and work collectively in the workshop to produce their design. Throughout week 7 to 12, they will take special consideration of sustainability concepts in their design.

The 'Sustainability' module runs from week 7 to week 12 and will see learners carry out the following activities:

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a) They will appraise the key reading and provide a short critical commentary and reflective account on their ideal definition for sustainability. This is a chance to digest the readings and decide the view that they align with, then try and apply it to their professional area. The exercise will be submitted on the VLE.

b) Following the initial submission, Learners will be asked to provide comments on one of their colleagues' posts. The exercise serves two purposes:

I. It mimics classroom discussions that take place in tutorials by asking each learners to express their ideas and then ask colleagues to respond and discuss.

II. It also provides an element of peer assessment where the feedback is diverse and reflects the background of the different learners, which would enrich the discussion.

The posts described above, and the instructions related to them are all made available on the VLE

c) Learners are asked to identify some of the key information from the readings and share it with their colleagues on the VLE as a way of framing their knowledge on the subject.

d) Some self-assessment exercises are also available on the VLE.

5 TEACHING RESOURCES

Multiplicity of resources are developed and made available and those created for the delivery of the programme are presented together with the intended kind of activities learners will engage with.

5.1 THE CATT BUILDING – THE STUDIOS

The building is part timber, part steel. The timber part is where the studios and communal areas are. This part will be used as a case study to offer a variety of examples, ranging from structural design to building performance, thanks to the implemented living lab approach. Further, the supply chain involved in the delivery of the building, with a special focus on timber elements (CLT, GLT, and insulated panels), will be mapped to offer additional insights on what's needed to calculate the embodied carbon and energy consumption of a building.

5.2 THE CATT BUILDING – THE WORKSHOP

The steel frame part of the building house a factory-like workshop and its intended use is presented in this section. The activities students will be likely to be involved in are described and the philosophy followed in the equipment of the space is explained. The activities may be different every year depending on the industrial partner, but will be of the type that can allow for the same level of assessment, requiring various pieces of knowledge and several skills.

5.3 INDUSTRY ENGAGEMENT

The link with industry, current partnerships and future possibilities, is described and the involvement of the sector in the professional development is depicted in this section. Industrial partners will be involved in the challenge-based learning system, presenting real life problems students will need to work on, and possibly solve, and collaborating in the preparation of scaled and full-scale models for the assessments, sharing their experience and knowledge or manufacturing specific elements that can't be made in the workshop. The CATT is already cooperating with several association, e.g., Timber Development UK or the Association of Sustainable Alliance for Sustainable Building Products (ASBP), and will expand its net of collaborations to increase this academic-industry cross-fertilization.

5.4 OTHER RESOURCES

Other teaching material available, such as case studies reports, or research outcomes, and related activities are presented in this section. Edinburgh Napier University (ENU), which is partner of NMITE in the establishment of the CATT, has been asked to help rewrite and update the knowledge library of the Timber Research and Development Association (TRADA), part of Timber Development UK (TDUK), key collaborator of the CATT. This material will be available for students and will help teachers shaping the different modules.

6 CONCLUSIONS

It is evident that the climate emergency is urging an action against the odds of survival and this paper reports on the approach taken by the NMITE in collaboration with national parties to account for some of the changes that need to be made in order to reach our targets for the climate change. The learning experiences reported in this paper culminated in the Short Timber TED courses that theorise a new agenda for education in the built environment, and each element of the courses is being trialled and enhanced.

The proposed short courses come with many types of challenges. For example, it is evident from the outset, that different learners come from different backgrounds (architects, technologists, structural engineers, timber production operatives, technical sales, project managers or even those switching to a built environment profession and seeking to expand knowledge). Therefore, learners have varying knowledge backgrounds and skill levels. This forms a continuum where on one side we have no knowledge and no skills, and on the other we have highly knowledgeable and highly skilled and everything else in between.

The challenge posed by this variety is mainly:

- Ensuring that the resources and knowledge offered in the course caters for the variety.
- Ensuring that the- learners all have the minimum Built Environment Knowledge and skills not only to attain the knowledge offered in the content, but actually to progress through it at the same pace and be able to get through it.
- Since the course is partially based on learning by doing, it was important to ensure that learners are able to progress through the practical tasks at a similar pace, given that they have different levels of skills.

This introduces a strategic challenge when it comes to teaching and learning because catering for all learners

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would require applying one of two strategies: a) use minimum baseline, where we provide the information from the baseline of the lowest point, but this could potentially make the more advanced learners feel they are not learning anything new, or b) use customised personal learning approach, where we help each individual improve according to their level.

The team uses a combination of both, where the online materials are baseline for all participants with the opportunity to advance using optional readings. Sometimes the texts selected, and topics are more generic to allow for a common grounds between different professional backgrounds.

In the 'Timber Design' module, learners are allowed to advance according to their skills and passion. Group work allows for a different dynamic where different learners use different skills and therefore complement the shortcomings of others.

This is a work in progress and is developing over expanding scale in terms of knowledge and geographic expansion. While the work started in our centre in Hereford, we are currently in the process of entering into agreement with another centre in Scotland to act as a regional hub to mirror and further our efforts within the UK.

ACKNOWLEDGEMENT

We would like to acknowledge the support of the New Model Institute for Technology and Engineering, (NMITE), Edinburgh Napier University (ENU), which is partner of NMITE in the establishment of the CATT, has been asked to help rewrite and update the knowledge library of the Timber Research and Development Association (TRADA), part of Timber Development UK (TDUK), key collaborator of the CATT.

REFERENCES

[1] Bathe K.-J.: Finite-Elemente-Methoden. Springer-Verlag Berlin Heidelberg New York, 2002.

[2] R. Mahnken. A Newton-multigrid algorithm for elasto-plastic/viscoplastic problems. *Comp. Mechs*., 15:408-425, 1995.

[3] Zener C., Hollomon J. H.: Effect of strain rate upon plastic flow of steel. Journal of Applied Physics, 15(1):22-32, 1944.

[4] Johnson G. R., Cook W. H.: A constitutive model and data for metals subjected to large strains, high strain rates and high temperatures. In: 7th International Symposium on Ballistics, 514-546, 1983

[5] H. Vegter, Y. An, H. H. Pijlman, B. D. Carleer, and J. Huétink. Advanced material models in simulation of sheet forming processes and prediction of forming limits. In *First ESAFORM Conference on Material Forming*, pages 499–502, 1998.

[6] J. K. Lee, G. L. Kinzel, and R. H. Wagoner, editors. *Proceedings of the 3rd International Conference: Numisheet '96*, 1996. The Ohio State University.

[7] M. H. A. Bonte, A. H. van den Boogaard, and J. Huétink. A metamodel based optimisation algorithm for metal forming processes. In D. Banabic, editor, A*dvanced Methods in Material Forming*, pages 55–72. Springer Verlag, Heidelberg, Germany, 2007.