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Article

Circular Research and Teaching Model (CReTeaM) for Higher Education Pedagogy: A Reflective Practice

Chukwuma Ogbonnaya

[1]Wolfson School of Mechanical, Electrical and Manufacturing Engineering, Loughborough University, Epinal Way, Loughborough LE11 3TU.
*Correspondence: c.ogbonnaya@lboro.ac.uk; Tel.: +447438503799.

Abstract: This reflective practice article proposes circular research and teaching model (CReTeaM) to enhance the enrichment of teaching and learning with research outputs, which in turns generates insights into new research themes or learning activities in a cyclic, impactful and continuously improving fashion. Case studies on how I demonstrated the CReTeaM pedagogical approach was instantiated using an air engine project, Questelligence theory and domain-based systems thinking. CReTeaM proved very useful in formulating research and teaching activities and generating evidence to advance knowledge through recycling and reusing the research outputs. The proposed approach could improve the research and teaching efficiency of teachers as well as their career and professional development whilst improving educational experiences of the students. Although this paper focused on engineering pedagogy, CReTeaM can be considered for research-informed teaching in other professional disciplines.

Keywords: Engineering Pedagogy; Research-informed Teaching; Academic Practice; Higher Education Teaching; Reflective Practice; Questelligence theory; Circularity

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1. Introduction

This reflective practice paper focuses on advancing research-informed teaching (RIT) mindsets which have been shown to have positive impacts on both the teacher and the students (Joseph - Richard et al., 2021). As a teacher in engineering, I tink that engineering education is practice oriented. I often explain that engineering has to be done to be learned as it is practice-oriented. Thus, effective engineering pedagogy is crucial for equipping engineering students so that they can function effectively in the industry. In my toolbox, inquiry-based learning, project-based learning and group work provide opportunities for real skills to be acquired by engineering students in a safe and supportive space where they are free to be critical, imaginative, curious, engaging, experimental, innovative and reflective. In my recent book (Ogbonnaya, 2024) titled “Domain-based Systems and Systematic Thinking”, I proposed that thinking in systems and applying systematics (i.e. study of methods to execute plans, objectives, goals and strategies) will be valuable skills as artificial intelligence (AI) become ubiquitous in its application. This is because large language models (LLMs) are redefining how knowledge is created and exploited to solve problems. Thus, effective pedgagogical approaches that empowers students to solve complex problems through active learning would be valuable across all disciplines in higher education institutions (HEIs) context.

Despite institutional interests in RIT, extensive theoretical and emperical efforts to mainstream RIT in practice is still lacking as there is no integrating frameworks or models to harmonously unify research activities and teaching activities for impacts in a sustainable way. From institutional perspective, (Robertson, 2007) observed that not being clear by government and higher education institutions may be creating an ontological crisis for those working in the academy. This argument appears more persuassive as many Higher education institutions across the globe create academic roles that focus on Research only, Teaching only and Research, Teaching & Enterprise. Deepening these roles as siloed roles may reduce the efficency and effectiveness of RIT at the levels of individuals, universities, nations and the global scientific community. On the other hand, integrating efficient and effective RIT strategy in HEIs, could improve their overall productivity and impacts across the globe.

Students have varying degrees of perception on RIT depending on their level of exposure in their curriculum. (Limniou et al., 2019) observed that research activities and students' interactions through dialogue and collaboration with their teachers and amongst their peers can be improved by studying real-example applications from research activities. Thus, RIT has both student and teacher's dimensions.

The overall aim of this paper is to critically reflect on my pedagogical approach for integrating research and teching to propose a CReTeaM as a systematic approach to translating outputs from research activities into teaching and learning materials, contents, activities and experiences. In turn, this enhances research activities in a circular, impactful and continous improvement fashion. Specifically, my objectives are to:

1. Propose CReTeaM as a pedagogical model for embedding research activities of the teacher and students into teaching and learning to facilitate project-based learning and inquiry-based learning.
2. Present a case study on the use of air-engine project within the proposed CReTeaM
3. Present a case study on how Questelligence theory was used to create research projects and how artefacts from the projects enriched teaching and learning.
4. Critically reflect on the opportunities for transforming CReTeaM into pedagogical framework for RIT.

The significant of this study is that it provides insights to researchers and teachers on the pathways for improving impacts of their research to enhance students' learning experiences. The contribution of this paper is that it highlights circularlity of RIT as a strategic approach to formulating pedagogical frameworks. Thus, HEIs and governments can improve how disciplianry research and pedagogical research are unified regardless of the nomenclature of academic job roles. Individual teachers and researchers would take personal responsibility to ensure that their research and teaching activities are impactful nationally and internationally.

The outline of the paper is structured as follows: Next section presents the literatures underpining the conceptual and theoretical framework of the CReTeaM. It also highlites the philosophical underpining of RIT mindset. Section 3 presents two case studies to illustrate how I applied the CReTeaM as a pedagogical approach. Section 4 presents a critical reflective practice on the topic in my classrooms and global implications for HEIs research and teaching while Section 5 presents the conclusions of the study.

2. Literature Review

2.1 Conceptual and Theoretical Framework

RIT mindset was proposed by (Joseph‐Richard et al., 2021) and they demonstrated that it has impacts on teachers' own practice in multidisciplinary contexts. CReTeaM was inspired by our previous work in energy and exergy efficiencies enhancement analysis (Ogbonnaya, Turan, et al., 2019) which used evolutionary approach to seek for the optimal configuration of modularisable integrated photovoltaic-fuel cell systems in terms of cost, efficiency and complexity. The finding shows that waste energy and exergy losses from a photovoltaic module reduce the overall effciency of the systems. However, if wastes and losses from the systems are targeted at all cost, at some point, the cost and complexity of the system would become suboptimal. Assuming that research outputs are energy inputs that could generate valuable outputs for the teacher and students, then, theoretically, there can be wastes and exergy losses. The question is therefore how energy inputs on research could be harneses for more impacts for the students and teachers using a reliable and practical model. Adopting CReTeaM could make research and teaching activities more meaningful and satisfying because of improved efficiency and effectiveness of a teacher.

Figure 1 shows the conceptual framework for CReTeaM assuming that generation of knowledge starts from research of the teacher or/and the students. Research of the teacher may include funded research, persoanl research and collaborative research. Research of students may includes final year project or research conducted during coursework. These research activities create diverse research outputs. There are specific benefits of CReTeaM for the teacher. For instance, experience is gained by the teacher, which enable the teacher to shape research and teaching experiences of subsequent students.

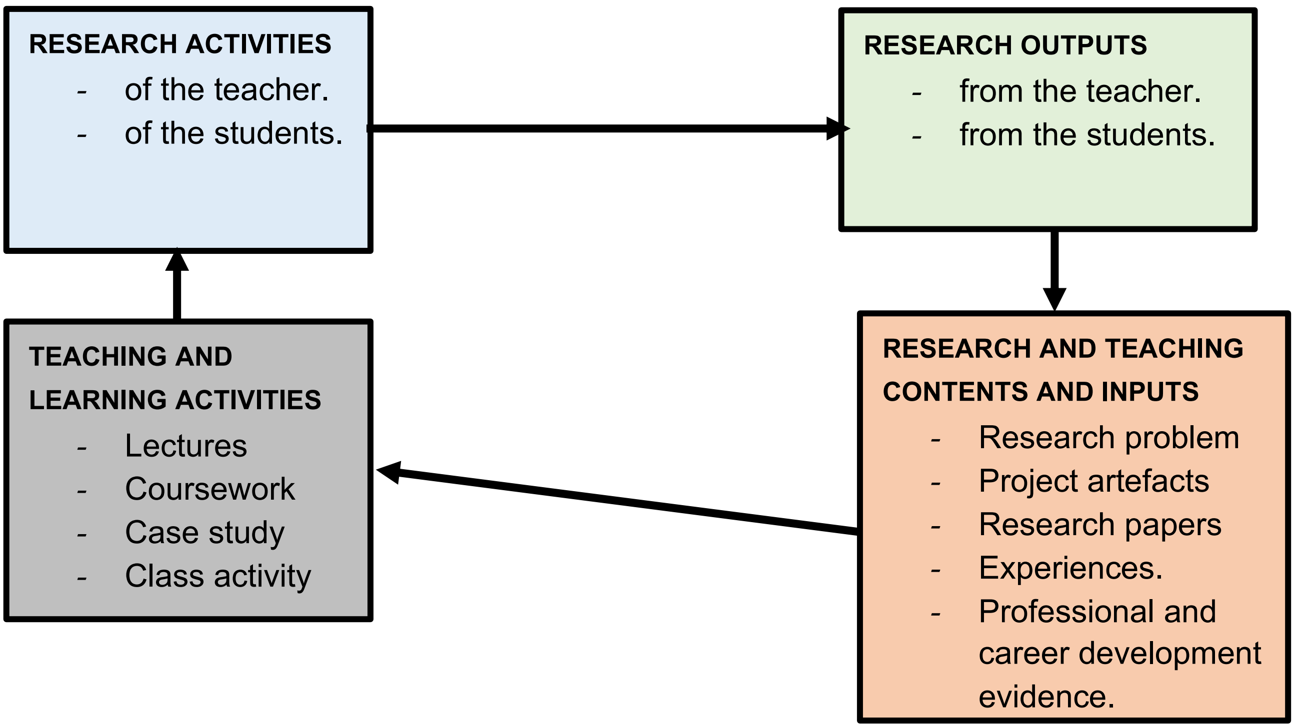

Figure 1: Circular Research and Teaching Model

The evidence from the teacher and students can also be used for career and professional development. In my case, evidence from my research activities as well as those of my students proved valuable during my application for Senior Fellowship of Higher Education Academy and during my promotion as I needed to provide evidence of impacts. Without intentional design and generation of evidence from practice using CReTeaM, the opportunities would have been lost. For undergraduate and postgraduate students, research for projects or coursework advance their knowledge and skills. Their outputs also act as inputs for further research and teaching. An example was a final year students who studied comparative analysis using inferential statistical method to study her data on bioinspired teamwork model and leadership and data generated from a student three years before her. She advanced the study by applying the model for studying teamwork and leadership in a context of engineering project management using the Project Management Institute's Book of Knowledge and Standards. Later, a case study will be presented on how an air engine project, a group Coursework for Part A students, was used as class activity and individual coursework for final year students. The air engine was an input into postgarduate lean manufacturing class activity and individual coursework. CReTeaM could serve as a pedagogical approach to enrich teaching and learning experiences of students in hands-on professional discipline.

The impact of RIT could be instrumental (to shape teachers practice or institutional policy), conceptual (to elucidate university teaching and reframing conversation on the epistemological implications of RIT) or capacity-building (to enhance personal and professional development) (Joseph - Richard et al., 2021). CReTeaM is build upon constructivist view of knowledge acquisition which elicit high degree of dialogue among students and knowlegde was often created through students' creativity, imagination and problem-solving skills whilst I take a position of a facilitator, providing useful feedback and asking questions that draw students into deep thinking and active learning. Section 3 presents two case studies to show how the CReTeaM was applied in my research and teaching activities.

3. Case Studies on CReTeaM in Higher Education

CReTeam has a cyclic framework containing four phases: Research Activities; Research Outputs; Research and Teaching contents and inputs; and Teaching and Learning Activities. The two case students will be presented using the four phases of CReTeaM.

3.1 Exploitation of Air Engine Project Artefact for Teaching and Learning

The case of an air engine project by Part A student involved the use engineering drawings of an air engine produced by a Lecturer. The engineering drawings were used to set project-based and team-based Coursework for Part A students in engineering management and prodduct design engineering students.

RESEARCH ACTIVITIES

Students were exepected to conduct own research and attend training at the workshop to enable them interprete the drawings, fabricate the parts at the engineering workshop and assemble the parts to make the air engine. The air engine was tested at the end of the project. Speed (rpm) and pressure (psi) data were recorded and plotted by the students as part of the Coursework.

RESEARCH OUTPUTS

Two outputs from the students' coursework which acted as inputs into further research and teaching were the air engine prototype and the test data. **Figure 2** shows the image of an air engine system. Without using CReTeaM as a pedagogical framework, research and teaching activities would have been concluded after assessment and feedback to students. Interestingly, using CReTeaM requires evaluation of the outputs from the research and coursework with an intention of deciding whether outputs from the projects or coursework could be integrated into further research and teaching activities. This empowers a mindset of continous improvement of research and teaching evolutionary and cyclically, thereby increase the efficiency and effectiveness of the teacher.

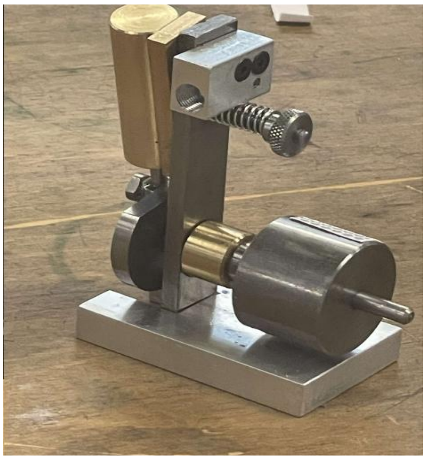

Figure 2: A prototype of air engine

RESEARCH AND TEACHING CONTENTS AND INPUTS

The outputs from the air engine project were used to set Coursework for MSc students in lean and agile manufacturing module. The students were asked to conduct as research and develop novel integration integrated photovoltaic-fuel cell energy system for distributed clean energy generation. This coursework was accompanied by my previous research papers I published from my PhD research (Ogbonnaya, Abeykoon, et al., 2019; Ogbonnaya et al., 2021; Ogbonnaya, Turan, et al., 2019) to enable the students learn more about integrated energy systems designs, sustaianble energy, supply chain management and risk management (Ogbonnaya & Hegarty, 2024). The test data was used to set a Coursework question on statistical process control and quality management. Students were asked to design a procedure for testing the air engine systems based on the experimental data from Part A students, assuming that their procedure would be applied in mass production of the air engine.

TEACHING AND LEARNING ACTIVITIES

Two of the air engines were disassembled and used as class activity in a lean manufacturing class. The Group activity required Group A to assemble the air engine without the assembly drawing but looking at an assembled air engine. Group B was given the assemble drawing as well as an assembled air engine. Group B assembled the air engine faster than Group A, which contributed to establishing the knowledge on visual management and standardisation of operations. Students observed and compared the two approaches and the lessons learned was very clear.

3.2 Mainstreaming of Questelligence Theory and Domain-based Systems thinking into Research and Teaching

The second demonstration of CReTeaM was based on a research I started as an independent research from 2010. The evolution of the research led to publications of books, templates, models, blogs and articles on the Questelligence Theory and Domain-based systems and systematic thinking. This case study will show how the Questelligence theory has been investigated by students and applied as framework for creative and analytical thinking for problem-solving.

RESEARCH ACTIVITIES

From my perspective as a teacher, the research activity focused on theory of thinking, theory of systems thinking and how the theories can be applied in communication, problem-solving, metacognition, games design, etc. The research has helped me to develope theoretical models and execute projects using systems thinking and systematic approach. **Figure 3** shows the 7 domains that uderpin Questelligence theory and domain-based systems thinking theory.

Extensive documentations of the theories can be found in my two books: Thinking, Knowing, Doing and Being (Ogbonnaya Chukwuma, 2021) and Domain-based Systems and Systematic Thinking (Ogbonnaya, 2024).

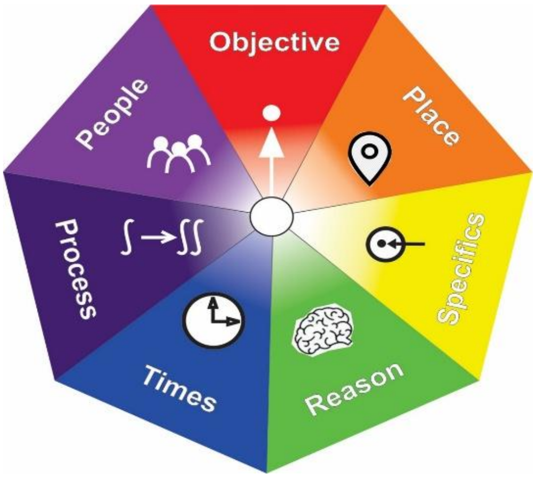

Figure 3: The Questelligence Domains

From the perspective of the students, their research focused on embodiments of the theories and demonstrating applications of the models I generated from my research. For instance, a student designed and prototyped a mechatronic spinner whereas another student designed and prototyped a low-cost mechanical spinner in their final year project. The intended learning objectives was to teach students Lean and Agile Design and Prototyping Methodology for product innovative. By conceptualising, designing, formulating the physics, fabricating components, assembling and testing of a prototype of an engineered system, the students learned how to translate conceptual ideas to prototype of products. This can be repeated whenever they need to generate prototypes to solve engineering problems.

Students have applied the domain-based systems theories in brainstorming and problem solving. For instance, students have studied supply chain management based on Domain-based risk management framework. This involves identification and classification of risks based on domains of objective, people, process, time and place using the reason and specifics domains.

RESEARCH OUTPUTS

Output from the students' research on the embodiment of the seven domains of Questelligence are shown in Figure 4(a) and 4(b). This prototypes were designed to facilitate teaching and learning of statistics and experimental probability at Primary and High Schools. The spinner can also be used to to create games for fun activities such as co-creating stories using domain-based thinking.

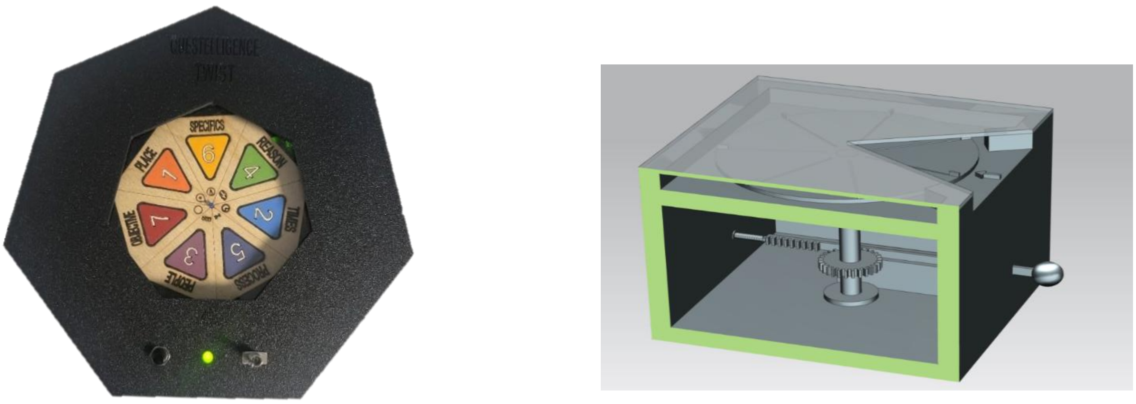

Figure 4: Prototypes of the 7 domains (a) Mechatronic Spinner (left) and 4(b) Mechanical spinner (right)

Figure 5 shows how a student applied domain-based thinking for brainstorming on possible areas to consider when formulating risk management framework for a food manufacturer. The student specifically defined the domains that could trigger risks and the next step was to translate the identified domains into risk statements, which can be assessed and managed. This approach ensures that risks are categorised into domains and managed through a systematic approach.

DOMAIN-BASED THINKING	PROCESS DOMAIN	PEOPLE DOMAIN	REASON DOMAIN	SPECIFICS DOMAIN
	Raw material sourcing – procurement of beans, tomatoes, spices & other ingredients from suppliers. Production of the baked beans and can. Blanching, sorting, cooking, packaging. Distribution and logistics – transportation from manufacturing facilities and distribution centres or directly retailers using lorries, trains and ships. Consumers purchase product from retail stores or ecommerce. Warehousing – Stored before shipping to retailers. Inventory management & fulfilment processes to ensure timely delivery of products. Quality Control – Maintaining standards in all stages of the supply chain.	Farmers – grow raw materials. Suppliers – supply materials. Manufacturing personnel – cooks, machine operators, packaging staff. Logistics and distribution – truck drivers, warehouse workers, logistic coordinators, DC managers. Retailers – Store managers, store buyers, shelf stocking. Consumers – Hotels, restaurants, households. Quality Control & Assurance – Quality control inspectors, conduct inspections, audits and testing. Labour shortages and skill gaps – Not enough labour to harvest crop, efficiency & quality of production.		
OBJECT(IVE) DOMAIN	**TIME DOMAIN**	**PLACE DOMAIN**		
Regulation compliance – food standards in UK, EU, USA. - US recipe includes molasses and pork fat whereas UK uses tomatoes, celery and Worchester sauce. Demand planning and forecasting – accurately predict future demands for baked beans on historical data sales and market trends to minimise risk of stock outs or excess inventory by aligning production and inventory levels with anticipated demand.	Lead time – minimising lead times are essential to maintain a responsive supply chain and meet customer demands timely. Production cycle time – efficient production cycle times help optimise resource utilisation, reduce costs and meet production targets. Order fulfilment time – Streamline to maintain service levels. Transportation time – Shelf life and expiry – minimize product waste, reduce inventory costs and ensure quality products. Repose time to supply chain disruptions. Seasonality – variation in crop yields across the year.	Haricot beans are grown and dehydrated in the US, Canada, China and Ethiopia and shipped to the UK for processing. Geopolitical instability – Political unrest, trade disputes, natural disasters. Transportation required – routes and modes available is dependent on locations. Ships and lorries. Weather – Affects crop yields. Legislation – Affects production requirements in different countries. Locations of processing facilities considerations – transportation links, distribution centres, location of customers, land cost, labour availability, international trade distributions, food safety compliance.		

Figure 5: Brainstorming activity using domain-based thinking

Figure 6 shows the result from an undergraduate student project which investigated supply chain risks in sportswear manufacturing and distribution. This particular question was based on objective domain to understand the motivations and considerations of sportswear customers in other to set performanance objectives for sportswear manufacturing.

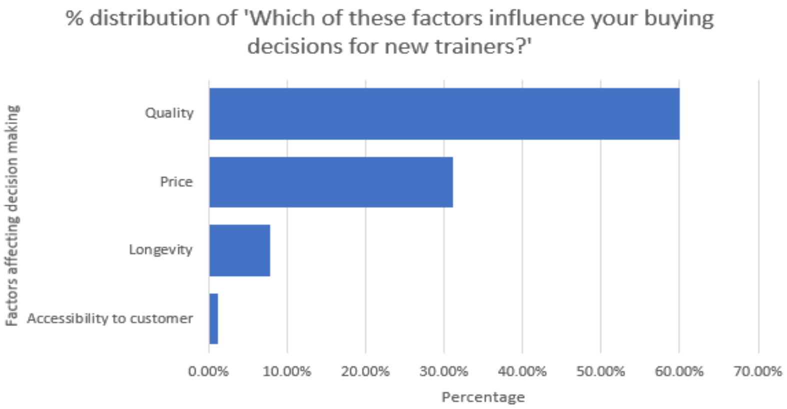

Figure 6: Factors influencing the buying decisions of sportswear customer

Figure 7 shows the result from an MSc project in which the student created an algorithm using Python to classify words respondents used as they answer open-ended questions. He categorised the themes into domains so that they can be translated into operational strategy and management activities as the analysis provided insights into the thinking of the respondents, with an assumption that what they mentioned most ranks high in terms of priority.

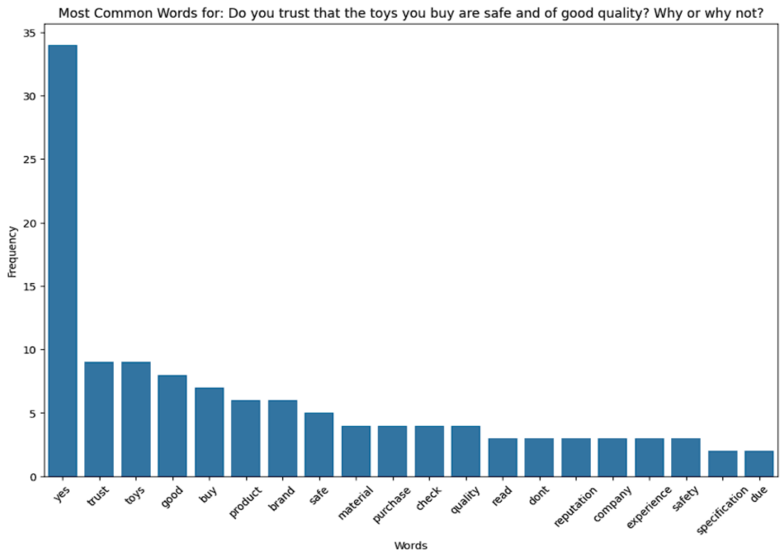

Figure 7: Thematic classification of responses for metacognitive insights

Table 1 shows the classification of risks using domain-based risk management approach applied in MSc module on engineering project managemnt. This output creates an exemplar that future students can study to create risk register for project and operations.

Table 1: Classification of risks using domain-based risk management approach

CLEANER ENERGY FOR HEALTH AND EDUCATION PROGRAMME RISK REGISTER

Risk ID:	Risk Description:	Domain:	Probability (1-5)	Severity (1-5)	Risk Rating (1-25)	Mitigation / Risk Management:	Responsible:	Current Status:
R001	Underestimation of the energy demand - the 50kW system may be insufficient	OBJECT	3	5	15	Pre-installation site audits of photovoltaic energy sites and possibly include scalable inverters.	Primary: Project Manager Secondary: Engineering team lead	ON-GOING
R002	Budget exceeded due to economic and exchange rate fluctuations	OBJECT	2	5	10	Use predictive financial models and allow a contingency financial reserve	Primary: Financial Control Secondary: Project Manager	ON-GOING
R003	Port delays at Lagos or Freetown	PROCESS	4	5	20	Ensure documentation is ready in advance of shipment, and allow a time buffer in scheduling plans	Primary: Supply Chain Team Secondary: Cargo Shipping companies	ON-GOING
R004	Supply Chain disruption	PROCESS	3	3	9	Use multiple supplier chains and ensure reserve stock is kept at the two hubs	Primary: Supply Chain Team	ON-GOING
R005	Lack of local workforces available due to the unavailability of skilled workers	PEOPLE	5	1	5	Bring in trained workers from Nigeria and South Africa and set up apprenticeship schemes within the schools	Primary: Engineering Team Lead Secondary: ADC	ON-GOING
R006	Changes in Governments or governmental procedures	PEOPLE	4	3	12	Ensure multi-level agreements are in place for the project that are signed for the regions of interest and not for the current operating governments.	Primary: Project Manager Secondary: Government ministries	ON-GOING
R007	Theft, vandalism or organised crime	PLACE	4	5	20	Secure all photovoltaic panels and introduce a community ownership model/scheme	Primary: Engineering Team Secondary: Local Community, ADC	ON-GOING
R008	Extreme weather events, such as flooding or heavy rainfall (monsoons)	PLACE	5	2	10	Allow for season supply scheduling and allow for installation and setup of photovoltaics in the dry season	Primary: Supply Chain Team Secondary: Project Manager	ON-GOING
R009	Island logistics complexity	TIME	3	2	6	Allow for seasonal shipments and pre-agreed times to the ports.	Primary: Supply Chain Team Secondary: Cargo Shipping companies	ON-GOING
R010	Cumulative delays across countries	TIME	3	3	9	Allow for parallel supply chain deployments to the different countries	Primary: Project Manager Secondary: Supply chain team	ON-GOING

RESEARCH AND TEACHING CONTENTS AND INPUTS

In the case of Coursework on domain-based risk management, students were required to identify, classify and evaluate risks that may apply to manufacturing operations or projects. **Table 1** was an output from risks associated with installing photovoltaic systems in schools and hospitals in five African countries. Domain-based risk management provided them with critical lenses to evauate the domain of risks associated with the project and the context of the project. This could be beneficial in clustering risks so that experts can manage them. For instance, people risks can be managed by Human Resources Managers or Team Leads. Process risks can be managed by technical staff. The Questelligence theory form a body of knowledge that could create research and teaching activities, thereby reinforcing skills of the student to creatively solve problems using domain-based systems thinking framework. Moreso, deeper reflection on the artefacts and results generated by the students tend to be so validating that I have developed more projects and teaching materials based on the theory.

TEACHING AND LEARNING ACTIVITIES

The Questelligence Theory and Domain-based Systems Thinking are epistemological and ontological models for thinking and metacognition. It leverages the theory of thinking and systems theory to generate and implement teaching and learning activities. The application of Domain-based Systems thinking (DBST) for teaching and learning includes creation of case studies in which students can explore risk identification and supply chain network design based on the 7 domains of Questelligence.

Recently, I desgned an MSc module on project management using DBST framework. The contents were organised in lectures focusing on objective domain of project management, people domain of project management, place domain of project management, process domain of project management, time domain of project management, Systems integration domain of project management using reason and specifics domains. This compressed the contents into 5 domains, which reduced the cognitive cost of understaning the principles, methodology, tools, techniques and processes of project management. The use of DBST framework for module design would include a General introduction lecture, five lectures on the five domains, a lecture on system-level integration and the last lecvel on case studies, depending on the type of the module.

4. Critical Reflection on ReTeaM as Pedagogical Framework

This paper advances the argument for circularity of RIT as a means of enrichment of educational contents, teaching and learning activities as well as improving the personal, career and professional development of a reserch-informed teacher. RIT mindset has already been proposed by by (Joseph - Richard et al., 2021). In their work, they stated: *"because of RIT, lecture design, delivery, assessment and student support activities have become more inquiry-focussed; study spaces have turned into collaborative learning contexts and classroom communications have become more comprehensible*". CReTeaM aligns with their proposition as it reflects my experience as a teacher in Higher education institution who has a significant understanding of UK Professional Standard Framework (UKPSF) as a Senior Fellow of Higher Education Academy. From experience, I believe that circularity of RIT can increase the efficiency and effectiveness of teachers across the globe. This is because losses of opportunities for impacts with research outputs would be dramatically reduced when circularity takes the center stage in the implementation of RIT based on CReTeaM.

From the case studies, the teaching and learning activities on air engine have led to listing further research project for undergraduate final year students which will focus on thermodynmic analysis (or energy and exergy analysis) of configurations proposed by the MSc students. The output of this final year project can be published in an international journal and subsequently used to create teaching content or further research activity. By recycling and reusing ouputs from research and teaching activities, the cycle continues with benefits of continous improvements based on lessons learned. The evidence and outputs can also be used to evidence my pedagogical practice and professional development thereby increasing the overall impact of the air engine project which may have been left unexploited after Part A coursework assessment and feedback.

Unlike the air engine project which was a practical activitity, QT and DBST were initially theoretical. Yet, the case study shows that it provides a creative, analytic and reflective framework for students for coursework and practical projects. The recent application of the DBST for module design and delivery was a testament on the utility of continous improvement in the use of CReTeaM as a pedagogical framework. The accumulation of knowledge from my independent research inspired results from the coursework and projects from students. These gave me the confidence that the entire body of knowledge of project management can be categorised into domains and the feedback from the student were positive. I look forward to reorganising old modules using DBST and supporting other teachers to learn the novel pedagogical framework. It is anticipated that the potential impacts of CReTeaM could lead to teachers creating teaching materials from existing and new research projects.

To increase efficiency and effectiveness of RIT in HEIs, CReTeaM needs to be embeded into institutional and national pedagogical frameworks. Thus, CReTeaM proposes valuing research from academics and students as inputs into advancing education of future generation in the fast-paced learning environment driven by AI tools and GenAI infrastructures. One practical approach to HEIs and national government support is promoting Open Access Publishing and sharing of teaching and learning as exemplified by MIT Open Courseware and other Open access educational platforms. UNESCO Recommentation on Open Science considers research outputs as public good for all humanity. As such institutions should support research and teaching approaches that makes novel and origanial scientific knowledge and effective pedagogical approach to be openly available, accessible, reusable, whilst promoting transparency, rigor, collaboration and ethical values.

5. Conclusions

This paper proposed CReTeaM as a circular model for RIT in Higher Education Institutions across the globe. I adopted reflective practice approach to utilise own experiences on how CReTeaM can enhance research, teaching and learning in a cyclic, impactful and continously improving fashion. Two case studies were presented. The first case study presented was on the reuse of an air engine project artefact from part A students for setting MSc coursework and creating class activity. The second case study demonstrated the development of a novel pedagogical approach using the Questelligence theory and domain-based systems thinking. Although, I have applied CReTeaM to advance both theory and practice of engineering in a higher education context, it could improve the efficiency and effectiveness of teachers whilst improving learning experiences of the students in other professional disciplines.

List of Abbreviations:

AI	Artificial Intelligence
CReTeaM	Circular Research and Teaching Model
DBRM	Domain-based risk management
DBST	Domain-based Systems Thinking
DBT	Domain-based Thinking
RIT	Research-intensive teaching
GenAI	Generative Artificial Intelligence
QT	Questelligence theory

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