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PEDAGOGIES OF INTEGRATION IN CHALLENGE BASED OR INTERDISCIPLINARY EDUCATION

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ABSTRACT

Integration is key characteristic of Interdisciplinary learning and often also of Challenge based Education. The definition and operationalisation in Engineering Education is, however debated widely. In this study we explored the tacit knowledge of Engineering Lecturers in HE education by doing semi-structured interviews. It yields suggestions for operationalising integration, boundary conditions and a peak insight into the beliefs and matches with theoretical literature.

1. INTRODUCTION

Grand challenges such as the Sustainable Development Goals (SDG"s) are used in Higher Engineering Education to shape challenge-based education. The idea of incorporation of the SDG's is often based on the necessity for students to acquire professional skills, such as learning to deal with complexity, collaboration in teams and across disciplinary boundaries [1]. Often these SDG topics are addressed in inter, trans or cross-disciplinary settings, meaning an integration of disciplinary knowledge (inter) or even lay-men knowledge (trans) is used to realise a solution [5]. The challenges adapt authentic contexts as a potential learning environment beyond formal academic education [2]. Exploit temporal available wisdom and power of diverse communities in vital coalitions of stakeholders [3] and add to different knowledge systems [4].

In this paper, we have focused on exploring the pedagogies of integration used in interdisciplinary or transdisciplinary approaches in challenge-based education. A key feature of interdisciplinary education, while engaging with challenges, is the integration of different disciplinary knowledge fields, which are used to solve societal challenges [4][5]. Arguably, interdisciplinary education is positioned by some as the next step to a post-disciplinary stage of Education [6] requiring a synthesising mind [7]. Arguably, students with a robust understanding between different disciplinary conceptualisations of vital themes, are likely to enhance integration, to help develop more coherent conceptual frameworks and increase productivity in the problem-solving process [8].

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Yet integration alone, as one means to this robust understanding is unravelled in numerous different ways. It needs to be realised through boundary-crossing [10], overcoming epistemological differences by clarifying the purpose of the outcome. It needs to be realised through disciplinary grounding, leveraging integration and taking a critical stance [11] or overcoming power differences [12]. Others discuss the integration in terms of education, such as the need for teamwork [13] or problem-based education [14] [6]. Therefore, the teaching of integration as an inter or -transdisciplinary competence can be difficult to operationalise in educational design [9] [12]. We noted very few authors, have come up with a description of the tacit knowledge available to Lecturers in Higher Education to tackle and address integration as a part of interdisciplinary competences to be acquired in challenge-based learning. It is an educational design challenge to be explored.

Tacit knowledge is knowledge acquired through practice and exercise in the performance of some tasks [16]. The idea is that the externalisation of tacit knowledge may provide insights into a range of integration beliefs and practices that may help theory formation of "Pedagogies of Integration" for teachers. The main research question in this paper is therefore: **What can we learn from the tacit knowledge of lecturers on “pedagogies of integration” in interdisciplinary learning contexts?**

2. Methodology

In this qualitative study, we interviewed 18 lecturers at our Technical University responsible for a minor or master course comprising interdisciplinary education. To find these lecturers, we consulted the course guide to identify which courses have been indicated as being interdisciplinary. The interview protocol has been based on the literature literature review model of van den Beemt [17], addressing the vision, education and support structures. The semi structured interviews have been transcribed and coded descriptively resulting in 11 emerging and principal codes, namely: vision, working methods, assessment, skills and knowledge, interdisciplinary problems, level of integration, objectives, involvement, reflection and evaluation. This paper focuses on the code level of integration. The code integration has been accorded to 220 excerpts across the 18 transcriptions by three coders. Interrater reliability (IRR) is used to establish if the information is collected in a consistent manner and show the identification of the 1st level coding is more than mere chance. The inter-rater reliability (IRR) was calculated, and is 0.71 showing a substantial degree of agreement among several raters, with a Fleiss ‘ Kappa (K).

Second level coding consisted of axial coding to get to grips with the data set and uncover the general patterns discerned and their interrelationships. This coding is done by using the headers in table 1 (results section) as a theme. Theme 1 is the phase of the action taken, while realising the educational design, such as programme design, and a refinement in the next column. Theme 2 is the mediating activities or the proposed intervention, and theme 3 is the outcomes or the anticipated integration of some sort if discussed. The themes and patterns will be discussed in the results section.

3. Results

The interviews show that when we talk about the "Pedagogy of Integration", each lecturer thinks of different moments in the design or performance phase of an interdisciplinary course—varying from programme design, instructional design at the course level to content methods, evaluation and integration methods (column 1). Column 2 is a refinement focused on what the function is of the tacit knowledge in the design of education. These results emerged from the tacit knowledge of education from the interviewee's and was influenced by their background knowledge in different disciplinary fields. The table below is a summary of the 2nd level axial coding of the interviews. Below table 1 the rows will be further explained.

Table 1. Pedagogies of Integration

DESIGN PHASE		MEDIATING VARIABLES	OUTCOMES (ANTICIPATED OR EXPECTED OR EXPERIENCED)
PROGRAMME DESIGN (3.1)	Structure resources	Support courses /mini lecture series/micro-lectures 3- pillared approach Cascading minor Retrospective design Disciplinary Pre-study	Integration of materials by students
INSTRUCTIONAL DESIGN (3.2)	Boundary conditions	Interdisciplinary topic (different disciplines) Mixed groups (disciplines, nationality, culture, gender) Entry profile of students Real life Cases Higher order knowledge Team-based teaching/facilitation Homologation	Stimulating Integration
CONTENT METHODS (3.3)	Content methods	Integrated design method Systems Engineering	
EVALUATION (3.4)	Assessment	Integrated final report /essay/diary writing	Higher order thinking skills (application, collaboration, discussion, presenting, synthesis) Impact and relevance in the field Writing & cohesiveness
INTEGRATION METHODS(3.5)	Working methods	Awareness activity House of the Future Cartographic Drawing Scoping Tohoku (Charette) Making a wiki Reflection	Connecting the dots Innovation Building interpersonal trust & empathy Testing assumptions Evaluation and adaptation

	Harris profile	Discovering values of disciplines Getting used to different jargon

3.1 Programme design

Structuring resources for students is mentioned as one of the approaches for integration of different disciplines. The mediating actions (table 2) are the three pillars approach, the cascading model and the retrospective design set up or a study in context. In the first three pillars approach topics from different major disciplines are offered in a programme– hence the "three pillars of a programme" comprising for example the topics environment, social aspects and economic aspects. These pillars are embedded in the curriculum at different levels and can consist of (1) entire courses (electives/mandatory), (2) support courses in projects in the format of mini-lectures to all the students and to a situation where (3) micro-lectures are given to a subgroup of students, who are required to share this knowledge within their project- team.

Another approach that was shared is the cascading model, in which in the

- 1st phase of a minor, the theoretical foundation is given,
- 2nd phase of a minor, a group assignment for the research analysis is given,
- 3rd phase of a minor, the involvement of an internal/external client is orchestrated.

In yet another “retrospective design set up”, a case is presented by multiple experts of different disciplines, local stakeholders are interviewed, and successively, a redesign is realised of the current situation or a situation that occurred in the past.

Finally, a last format is discussed where a problem is studied in a disciplinary context. After the problem definition, data collection and analysis are realised, groups are redistributed across interdisciplinary groups to realise an integration of disciplines into the solution. In each design the students are expected to realise the integration with the knowledge on offer at the beginning of a programme.

3.2 Instructional Design

When we consider the typical characteristics of an interdisciplinary learning context, all the interviewee's described boundary conditions, which might be necessary to trigger integration of disciplines. These boundary conditions are linked to the topic, teamwork vs individual, the backgrounds of students and the collaborative attitude of the lecturers themselves.

There needs to be a content topic that can be addressed in an interdisciplinary way – meaning it should be open, have sufficient scope and involves different types of knowledge.

In most interdisciplinary contexts, students work in interdisciplinary teams of 3-5 students per group. It means the students are mixed, consisting of different disciplinary backgrounds, different international and cultural backgrounds, and gender balanced. The group composition is of crucial importance one of the interviewee's said:

"different disciplines bring crucial skills to the table to come to an innovative solution."

Sometimes, however, the interviewees indicate that interdisciplinary learning occurs at an individual level.

The boundary condition background is determined by the entry-level profile of a student. They are, for example, asked for a motivation letter, and different background criteria. The criteria are used as selection mechanism such as explicit knowledge of particular disciplines for admission e.g. 1 designer in the group. Enthusiasm goes a long way, however, as admission criterium, it is cited by all.

The boundary condition collaboration between teachers elicits the following observation. It is suggested that real-life cases stimulate interdisciplinary collaboration between students, especially when these cases involve the use of higher-order thinking skills. Intuitively, these courses should involve teachers with different disciplinary background. The impact thereof on integration becomes tangible when there is close collaboration and matching of content matter across the different content topics provided by the teachers. This matching of activities is not always taking place. Often the teachers do their content/activity (provide lecture/group work) and return to their home base after teaching the students and do not talk to other staff. Therefore, team-teaching and continuous adaptation to what is going on in the course tend to be more critical than in regular courses.

"*Making schema's which show how content is connected, methods and techniques to fill the toolbox connected to the backgrounds and the formulation of final qualifications of a sub-specialisation are necessary to make things work." At teacher and student level.*

It requires a specific profile of Interdisciplinary teachers to make interdisciplinary integration work [21].

3.3. Problem definition and Content Methods

Topics or problem definitions should be interdisciplinary by nature and allow for a multiplicity of solutions. Interdisciplinary problems can be characterised as open problem definitions of real life, societal and complex situations. The solutions space typically involves consultation with multiple stakeholders, involving multiple perspectives and different scientific paradigms. Sometimes the programme offers an overarching methodology for solving interdisciplinary problems, such as socio-technical systems, systems engineering, design methodology, design thinking or other problem-solving techniques stimulating integration. These characteristics overlap with many CBE courses [19].

3.4 Evaluation

The realisation of integration is one of the most difficult as no clear criteria for assessing the success of the integration in the final results exist. The assessment methods tend to be essay writing or final report/presentation in which content of different disciplines is integrated. Although this integration is nowhere explicated, general agreement amongst the interviewees seems to imply that it should demonstrate higher-order thinking skills. Higher-order thinking skills are skills such as application, collaboration, discussion, presenting and synthesis. Another measure is the impact, relevance and cohesion of a report/presentation. However, none of these three parameters is per se a measure of integration. The best idea was the daily/weekly journal/log writing in which teams have to explicit (1) how things were done, (2) what was going well, (3) what needs to be completed.

3.5 Integration Methods

There was a range of different working methods used for integration at different phases in the courses of the interviewees.

Starting up
Awareness activity, the house of the future and scoping are used at the beginning of an interdisciplinary course/challenge.

Awareness activity
One lecturer had a workshop in which students are grouped in their discipline, solved the problem and presented to other groups from different disciplines. They became aware of the differences. The next step, in the same workshop, was to mix the groups and come up with approaches/solutions for the same problem that showed the realisation of integration.

House of the Future
In the house of the future, students from different disciplines make a house together they would like to inhabit. Different disciplines integrate their knowledge, ideas and values to make the house. It is a warming-up exercise in which students get to know each other. The exercise creates empathy and trust between the different participants hopefully stimulating integration of other solutions proposed by a team.

Scoping
Scoping can be a part of the Tohoku method but can also be realised independently. It entails students sharing their disciplinary values and how they would like to see activities done with a number of guiding questions.

- What information do you need from the other participants and stakeholders?
- How can other peers/stakeholders provide that information to you?,
- What do you need to give to others?
- How can participants define different solution routes?
- "How do disciplines relate to each other?

Finally, they draw diagrams of what they need from each other and the participating stakeholders.

Continuous design working methods for integration
The next set of working methods for integration are used to critically question the process during the entire problem-solving process.

Tohoku (Charette)- The Tohoku method – was named after the project case, which happened in Tohoku, Japan. The basis of this method is the Charette method and entails a reflection onto solutions for a problem by making the choices explicit for solutions x and y. For example, by using the People, Profit, Planet, Project concepts. An iterative confrontation with other disciplines to reconsider these 4 P's choices is an essential part of the activity. Successively, of course, to adapt solutions to dilemma's that get more weight during the process. The language of the group members and the matching of different disciplines such as thinking at different scale levels or systems is an integral part of the realisation of an integrative (design) problem solution. The innovation is connecting the dots between a variety of topics that are typically not considered. Continuous presentations to make each other's perspectives insightful is a necessity. The methods are described expertly in the article by Hooijmeijer [20].

Figure 4 Schematic representation of the charrette approach, each colour is a participating discipline with their scope, set of concepts and measures.

Cartographic drawing
This is a method where local stakeholders share their values and ideas. These values and ideas are made tangible in student design solutions drawn on geographic maps. Including red structures students do not want in the design and green structures students do want in their design. After each round of stakeholder consultation, students redraw their map and get longitudinal insights into the design process [19].

Making a forum or wiki
In which they do activities together and jointly write towards the solution of the problem. To make it acceptable, they need to iteratively make their co-writers understand and explain what they found in theory and practice.

Reflection
This is more generic involving the listed questions in the table but can relate to any **questions triggering reflective activities.**

- How do disciplines relate?
- What are the boundary conditions of a discipline?
- What Inputs do they need from each other?
- What information do they need from other people?
- What do you need to give to other people?
- Understand what each one is doing?
- What needs to be adapted?
- What are the values embedded in your group?
- How would you like the design done?

Harris profile
In evaluating their solution, students identify criteria based on business aspects, business criteria, and technological criteria. The students give each of these criteria a score and make a mathematical decision matrix based on their scores to come to a solution/concept [25].

Anticipated and observed outcomes of Integration Methods

Outcomes can best be illustrated with a quote:

"They learn how to give up their assumptions or abandon their preconceptions of the way people work and communicate and reconstruct it together with the others. Because, again, just with the word of what a design means, between an architect and an engineer being much different on that, we can no longer keep our preconceived ideas of what a design is and still produce a useful end product with these other people who have a much different idea."

3.6 Outcomes

Finally, there are, of course, also some obstacles, pitfall mainly related to integration.

Exploring different scientific perspectives is the critical activity to capture different knowledge-bases and have a group come to results. The latter can only be achieved according to some of the interviewees, at the master level. Preconditions for effective integration according to the interviewees is that students minimally need to master the following skills:

- awareness of different problem perspectives which includes an understanding of different scientific paradigms.
- Reflection and integration by means of stimulating discussions.
- Communication skills to overcome communicative obstacles, such as different jargon, opinions, and paradigmatic differences.
- Creativity skills are another key element to deal with the uncertain situation.
- working methods typically used to garner integration are design assignments, integrative project work on challenges, individual research.

Drawbacks and obstacles for integration in interdisciplinary settings are, for example, that students divide their tasks based on their disciplinary knowledge. Each student tends to pay attention to one particular part of the group work and forgets the remainder. The reasons might be that students lack the skills to search for interdisciplinary solutions as there are no books available! They need much support to make this integration happen.

Interpersonal and communication skills may become top-heavy in the process of disciplinary integration. Time spent on communication cannot be spent on design and in-depth work. Consequently, lower content standards, such as a lack of depth and focus in work, may be accepted by the teachers, as the purpose of this type of solution finding is different from disciplinary work.

Finally, the lack of availability of teachers with an interdisciplinary background and funding structures may result in the obstruction of the integration of multiple disciplines.

4. Conclusions and Discussion

In this overview of “pedagogies of integration” used in practice, the view emerges that the list of interdisciplinary competencies mentioned by Boix Mansilla: (1) purpose of integration in interdisciplinary education, (2) disciplinary grounding, (3) integration and (4) critical awareness of what the others bring to the table, are tacit values of interdisciplinary education at investigated institution [12], [11]). The tacit knowledge is in line with the literature, where integration is described as "the leverage of different knowledge and methods from different disciplines to understand a phenomenon or the advancement of knowledge" [11]. Typically, this separates interdisciplinary learning activities from other types of education. We further noticed that the programme/course design/integration exercises are well articulated and even researched. In line with other literature, however, assessing integration seems to be following the traditional assessment lines, meaning there is no suitable method yet to assess integration [17]. Finally, the research provides several tangible exercises to operationalise integration at different levels of course design.

Some limitations may have influenced the final results. The number of lecturers involved was limited and particularly represented the sustainability and design engineering fields. From the social sciences, business students were involved. It is recommended to do another study, which includes data triangulation of the (perceived) student results. confirming the intentions of the lecturers on the programme design, working methods and additional findings. Equally, these results are from the engineering sciences. It would be of interest to find out if different disciplinary domains would provide additional insights into what works and does not work for integration of disciplinary knowledge in interdisciplinary higher education.

Further research will focus on the impact on student learning and societal change.

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References

1 Nowell, L.S,.Hayden, K.A, Dhingra, S., Andrews, K., Gospodinov J, Liu C., (2020), Grand Challenges as Educational Innovation in Higher Education: A Scoping review of the Literature, *Education Research International*, Volume 2020, Article ID 6653575, 39 pages, https://doi.org/10.1155/2020/6653575

2 Xhomaqi, B. , Todd, A., Boivin, P., Baez- Ramirez, J (.eds) (2019), 21st Century Learning Environments, *LLLP- Postion Paper*, European Union Support & EARLI

3 Walsh, A.E.J. (2015), *Beyond unreasonable doubt; education and learning for socio-eological sustainability in the Anthropocene*, Inaugural address WUR 17 dec. 2015)

4 Menken, S. &. Keestra, M eds. (2016), an Introduction to interdisciplinary research; *theory and practice*, ISBN: 9789462981843

5 Repko, F. (2008) Interdisciplinary Research. Thousand Oaks, CA/USA: Sage.

6 Braßler, M. (2020), Interdisciplinary Teaching and Learning – Theory, Empirical Results, and Practical Implications, ICERI, DOI: 10.21125/iceri.2020.2072

7 Gardner, H. (2006). Five Minds for the Future. Boston, Mass.: Harvard Business School Press.

8 Gouvea, J.S., Sawtelle , Geller, B.D. &Turpen, C. (2013), Framework for analyzing interdisciplinary tasks: Implications for student Learning and Curricular Design, CBE- Life Sciences Education, Vol 12 (2), pp 187 - 205_

9 Tripp, B., & Shortlidge, E. E. (2019). A framework to guide undergraduate education in interdisciplinary science. *CBE—Life Sciences Education*, *18*(2), es3. https://doi.org/10.1187/cbe.18-11-0226

10 Fortuin, K, (2015), *Heuristic principles to teach and learn boundary crossing skills in environmental science education*, PhD thesis, Wageningen University, NL , ISBN 978-94-6257-483-0

11 Boix Mansilla, V. (2016), “Interdisciplinary learning: A cognitive-epistemological foundation” in Oxford, *Handbook of Interdisciplinarity, in* Frodeman, R..and Klein J., eds.), pp. 261–275, Oxford/UK: Oxford, University Press.

12 Kalmar, E. & Stenfert, H. (2020), Science Communication as a Design Challenge in Transdisciplinary Collaborations, Journal of Science Communication, Vol 19 (4), https://doi.org/10.22323/2.19040301

13 Tripp, B. & Shortlidge, E.E. (2020), Crossing Boundaries; Steps Towards Measuring Undergraduate Interdisciplinary Science Understanding, *CBE- Life Science Education* (19) (2), ar. 8, pp 1-16, DOI: 10.1187/cbe.19-09-0168

14 Loje, H, Hammar-Anderson, P, Grex, S. (2017), Improving innovation and multidisciplinary competences among bachelor of engineering students, 45th SEFI – Conference, Azores Portugal.

15 MacLeod, M. & Van der Veen, J.T. (2019), Scaffolding interdisciplinary project-based learning: a case study, European Journal of Engineering Education 45(3):1-15, DOI: 10.1080/03043797.2019.1646210

16 Yasouka, 2017, Collaboration Across Professional Boundaries – The Emergence of Interpretation Drift and the Collective Creation of Project Jargon, *Computer Supported Cooperative Work* (CSCW) (2015) 24:253–276DOI 10.1007/s10606-015-9229-2

17 Van den Beemt, A.| MacLeod, M,| Van der Veen, J., | Van de Ven, A.| van Baalen, S.| ,|Boon, M. (2020), Interdisciplinary engineering education: A review of vision,teaching, and support, Journal of Engineering Education, Doi: 10.1002/jee.20347

18 Kohn radberg, K. , Lundqvist, U., Malmqvist, J. &Hagyall Svensson, O. (2018), From CDIO to Challenge-Based Learning experiences- expanding student learning as well as societal impact? European Journal of Engineering Ed. Vol 45(4) pp 1-16, DOI: 10.1080/03043797.2018.1441265

19 Kothuis, B., Brand,N, Sebastian, A., Nillessen Jonkman S.N.(2015), Delft Delta Design, Houston Galveston Bay Region, Texas, USA, Delft University Press, ISBN 97894611864901

20 Hooimeijer, F. L., Areso Rossi, A., van Overstraten-,Kruijsse,F., Oosterom, M., Moncrieff, N., Suijkens, S., & Grigoris, X. (2020). Transferring inter-disciplinary flood reconstruction responses from Japan to the Netherlands. International Journal Sustainable Future for Human Security, 7(2), 11-23