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Exploring the curricular and pedagogical decision criteria for research-based learning design in undergraduate studies

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ABSTRACT

Learning design has a multifaceted nature requiring a range of course- and institutional considerations. Analyzing the decision criteria's influence on research-based learning design helps understand the causes of the success/failure of the approach in achieving the teaching goals to improve the study programs. This study explores the interrelationship between the curricular and pedagogical criteria for research-based learning design decisions at the undergraduate level. For this purpose, the DEcision-MAking Trial and Evaluation Laboratory (DEMATEL) method is used to systematically analyze the decisive criteria and their causal relationships. Feedback from education professionals and university professors from Scandinavian universities is used to validate the pedagogy decision framework and provides input into the DEMATEL method. The student's role in the course is identified as the central criterion, featuring the highest level of interactions in the network of curricular and pedagogical decision criteria. Results are supportive of the identified institutional and course-specific criteria as prerequisites for the study outcomes.

1. Introduction

Research-based learning is a relatively new approach in undergraduate education. Acquiring research skills early in undergraduate studies provides students with a practical level of understanding of the subject that prepares them as producers of knowledge (Walkington et al., 2011); this also improves student accessibility, inclusion, and retention (Eaton et al., 2022). Several undergraduate programs have recently implemented this learning approach (Bowyer & Akpinar, 2022; Radu, 2018; Setiawan, 2020). Research-based learning design requires more development in the academic literature; a direction that inspires the present study.

Learning design in institutionalized education consists of determining the learning activities that students have to do, evaluation/assessment, the resources needed, and the support tools that facilitate the learning process, as well as the organization and implementation of instruction and learning models (Hernández & Kilar-Magdziarz, 2023; Schmitz et al., 2017; Sirait et al., 2023); these decisions should be approached conscientiously for a well-informed learning design. Various curricular and pedagogical criteria must be considered in learning design decisions to ensure high-quality study programs and plans. The decision criteria and their interactions determine the success/failure of the teaching method. Besides, knowing the underpinnings of the curricular and pedagogical decisions helps improve the study programs.

Decision-making in pedagogy, particularly learning design is of practical significance but received limited attention in the academic literature (Tawfik & Gatewood, 2022). From the seminal studies, (Alammary et al., 2015) developed a multiple-criteria decision analysis method to study the blended approach for learning design. (Stefaniak, 2021) studied dynamic decision-making as a means for promoting creative risk in instructional design pedagogy. (Stefaniak, Luo, et al., 2021) developed a conceptual framework that supports decision-making in digital learning environments. Most recently, (Chen et al., 2023) overviewed the instructional approaches and decision-making strategies for improving learning design. Research-based learning design decisions remain underexplored.

It is essential to understand the causes of an underperforming study program in achieving learning outcomes before taking improvement actions. Decision frameworks on research-based learning design carry with them a certain cachet; analyzing curricular and pedagogical decisions facilitates program planning and evaluation through decision aid. There are limited studies at the intersection of pedagogy and

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decision analysis (Lucas et al., 2017). Brew (2013) conceptually modeled the curricular and pedagogical choices for engaging students in research and inquiry. To the best of the authors' knowledge, there are no academic articles to investigate learning design decisions, in general, and research-based learning in undergraduate studies, in particular. Systematic decision analysis methods should be used to improve the know-how of research-based learning in undergraduate education. The following research questions are defined to bridge this research gap: (1) What are the main criteria to consider in research-based learning design? (2) How do the interrelationships between these curricular and pedagogical criteria impact research-based learning design? A literature review is used to answer the first research question. The second question is answered using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method. Feedback from education professionals and university professors from Scandinavian universities confirms the criteria list and provides input into the DEMATEL method. Overall, the study objective is to structure the learning design decision problem and provide a steppingstone for future research on multi-criteria decision-making in the field. Educators wishing to improve their research-based learning courses, or those who need to implement research-based learning will benefit from understanding the underpinnings of learning design decisions, including the criteria and their interrelationships.

The rest of this article begins with a literature background in Section 2. The research method is briefly explained in Section 3. Data collection and the decision criteria are presented in Section 4. Section 5 presents the results followed by insights into the practical implications and findings. Finally, the study is concluded in Section 5.2 by summarizing the answers to the research questions and providing suggestions for future research directions.

2. Literature review

Research-based learning is a relatively new concept, nevertheless, the idea of involving students in the learning process dates back to Humboldt's conceptualization of university as a venue for exploring new knowledge. This method of learning is in contrast with the old school system where students do not participate in knowledge development but are only taught the existing knowledge (Annala & Mäkinen, 2011).

Modern education recognizes universities as the place for knowledge development (Hu et al., 2014). The early studies argued that the university's focus on publishing leads to reduced teaching quality due to a variety of reasons, such as limited time for teaching and preparations. This, in turn, leads to more students being brought together in large classes with conducting research becoming a secondary objective. The idea of students participating in research projects was first introduced in the study of Boyer (1990) and gained recognition in recent years (see (Tight, 2016)).

Research-based learning has numerous advantages (van der Rijst, 2017). As a prime example, research and teaching provide a valuable synergy for more effective learning. Students can better understand the subject, have autonomy, and personalized learning experiences. Research-based learning also improves their problem-solving, and critical thinking skills. Furthermore, research requires practicing the learned knowledge, which is likely to improve situation-awareness skills for better decision-making (Mason, 2020). These advantages are congruent with pedagogical approaches such as inquiry-based learning (Furtak et al., 2012; Santana-Vega et al., 2020; Spronken-Smith & Walker, 2010). On the importance of research-based learning, outcomes of research-based learning are perceived as connected to 21st-century skills and employability because of its relation to real life (Arifin et al., 2022). That is, students can relate their learning experience to future job prospects and appreciate the real-world examples of the learned subject (Healey et al., 2010; Nikolov et al., 2020; Smyth et al., 2016).

Research projects are often carried out by faculty with a common perception that postgraduate education qualifies students to engage in research in a meaningful way. From this viewpoint, undergraduate students must be first taught the current knowledge (Barnett, 1992). Such perception among faculty, students, and administration is recognized as one of the greatest barrier to implementing research-based learning (Brew & Mantai, 2017; Buckley, 2011; Wilson et al., 2012). The negative view on implementing research-based learning in undergraduate studies is likely to have originated from a lack of past personal experience (Brew & Saunders, 2020). This may result in underperforming outcomes. It is important to understand the underpinnings of the learning design decisions before taking improvement actions; a much-needed nuance in implementing research-based learning, which is studied in the next sections.

3. Method

As a systematic approach for decision analysis based on experts' opinions, DEMATEL (Fontela & Gabus, 1976) investigates the criteria's inherent relations to make sense of the decision foundations. This approach of utilizing the qualitative opinion of experts is constructive for studying new topics when there is little or no evidence to generate meaningful insights into the problem. DEMATEL structures the problem, explains the system underpinnings, and prioritizes the criteria for possible improvement in the system (Badri-Ahmadi et al., 2022; Falatoonitoosi et al., 2013). In this study, DEMATEL analyzes the role of different curricular and pedagogical criteria in research-based learning design decisions. A three-phase approach described below is used to arrive at the results.

3.1. Phase I: Data collection

Data was collected in the form of the Direct Relationship Matrix (DRM) asking about the extent to which each criterion in the row influences the other criteria in the columns. The possible responses are selected from "No Influence", "Low Influence", "Moderate Influence", "High Influence", and "Very High Influence", and are entered into every cell of DRM. Simple averaging is used for aggregating the opinions of the experts.

3.2. Phase II: Data processing

The process starts with normalizing DRM by dividing every element by the largest value amongst column/row summations. Next, the resulting matrix is multiplied by the reverse of its difference from the identity matrix. The output of this procedure, called the Total Relationship Matrix (TRM), represents a convergence of the cell values as a result of infinite rounds of multiplications, indicating all the possible ways of direct and indirect relationships between the criteria.

3.3. Phase III: Prominence and net-causation analysis

The sum of TRM rows and columns indicates the total influence of criterion i on the remainder of the criteria (D_i; dispatched) and the total influence received by criterion i (R_i; received), respectively. The criteria prominence signifies the total dispatched and received influence with larger values indicating the central role of a criterion in the system. The curricular and pedagogical decision criteria are categorized into the cause or effect classes considering the difference between the dispatched and received influences, the so-called net causation; the criteria with a positive valuation of this measure are the system influencers while the rest are mostly influenced by the others. In decision-making, focusing on the most influential curricular and pedagogical decision criteria is more likely to result in a major improvement.

4. Data collection and decision criteria

Expert-based methods can serve as a fair alternative to empirical ones, especially in the absence of empirical data (Assis et al., 2019; Karoulis et al., 2006). In contrast to data-based methodologies, expert-based methods, like DEMATEL, can rely on a small sample of experts (Rezaei et al., 2012). This study uses inputs from seven university professors with backgrounds in education/didactics. Table 1 summarizes their background and years of experience. These decision-makers are identified as our 'experts'.

The data were collected in two rounds of interviews. In the first round, an initial list of the curricular and pedagogical decision criteria, which was identified through a literature review, was presented to the experts to improve its concreteness relative to practice. Table 2 provides the final list of decision criteria approved by all of the experts. The twelve criteria and five linguistic terms were considered to establish the basis for the rest of the data collection procedure. The second round provided a guideline on how to fill up the DRM matrix asking the question "When making curricular and pedagogical decisions in research-based learning for undergraduate studies, to what extent does the criterion in the row influence the criterion in the column?".

5. Results and discussions

5.1. Results

Tables 3–4 present the data processing outcomes based on the experts' pairwise evaluation of direct relations between criteria. Table 3 shows the total relationship values each of which specifies the total relationship between the pair of criteria. A threshold of average plus one standard deviation ($=0.4369$) is considered to identify the most notable relations. Notably, the '*Inquiry form*' imposes the greatest total (direct and indirect) impact on the '*Students' role in the course*' in the network of curricular and pedagogical decision criteria. The '*Students' role in the course*' is also impacted greatly by the '*Area of study (Discipline)'*. This table confirms that many of the considered curricular and pedagogical decision criteria for research-based learning design interact with the extent of students' involvement in the classroom and the learning outcomes.

Table 4 lists the total dispatched and received influences in DEMATEL analysis based on which, the net causation and prominence values are calculated. Prominence can be interpreted as the centrality of a criterion in the research-based learning design decisions and net causation explains its contribution. Criteria with great prominence are highly intertwined and their misalignment with the rest of the criteria is likely to result in underperforming learning programs. Criteria with highly dispatched influence should be given special attention when taking improvement actions because their possible improvement is expected to bring about overall improvement in the curriculum. Considering the prominence values greater than the average (8.611), $\{C_1, C_2, C_4, C_5, C_{12}\}$ are recognized as the driving criteria due to positive net-causation signs; $\{C_3, C_6 - C_{10}\}$ are the impact criteria with a negative net-causation.

Table 1
The panel of experts.

No.	Position	Experience (Years)	Field
1	Senior Lecturer	20 +	Social studies didactics
2	Lecturer	15 +	Education
3	Associate Professor	5 +	Science and educational development
4	Lecturer	5 +	Mathematics didactics
5	Professor	20 +	Mathematics and science didactics
6	Senior Lecturer	10 +	Business administration didactics
7	Professor	25 +	Public administration and qualitative research

Table 2
List of curricular and pedagogical decision criteria.

Perspective	Decision Criteria	Definitions or Explanations
Institutional	*C1) Area of study (Discipline)*	Whether the learned knowledge is specific to a discipline (i.e., science, technology, engineering, mathematics, etc.) or interdisciplinary-based.
	C2) Audience for the research	People who may benefit from the processes and/or findings of the inquiry (e.g., students, teacher(s), community professionals, regional companies, and SMEs). This impacts the availability of funds and other supports.
	C3) Learning mode	Whether the courses are in the form of synchronous (e.g., in-person, hybrid, fully digital) vs. asynchronous (e.g., video lecture, digital discussion groups, etc.).
	C4) Local and institutional culture	Surrounding culture that may impact students' learning (e.g., Workload, students' and teachers' attitude and motivation, interdisciplinary environment)
	C5) Institutional resources	This includes the availability of infrastructure, well-equipped laboratories, software, and technologies to support the inquiry.
Course	*C6) Concreteness of the inquiry*	The depth and level of knowledge the students are expected to learn during the inquiry and whether the learning outcomes are open-ended or close-ended.
	C7) Inquiry form	Whether the research is student/process-centered or outcome/product-centered; is it carried out on an individual or collaborative basis?
	C8) Learned knowledge and/or skill	Types of knowledge (e.g., new, fixed) and/or skills (e.g., collaboration; self-regulated study; research; communication; presentation; etc.) to be developed through the inquiry.
	C9) Outputs of the course	The type of required outputs and/or assessments designed to support students' learning through the inquiry. This includes exams, presentations, and reports.
	C10) Students' role in the course	Level of autonomy and the aspects of participation of the students throughout the inquiry.
	C11) Authority of the decision maker	The party who designs the curriculum (e.g., university/Department/ Teacher) and makes the curricular and pedagogical decisions.
	C12) Student's prior knowledge	Students' background, abilities in learning, academic competence, and prior experience with research-based learning

'*Area of study (Discipline)*' dispatched the largest total influence in the network. That is, planning and evaluation strategies for improving the learning experience are discipline-specific (Hardré et al., 2014). '*Students' role in the course*' appeared to be the criterion that is influenced the most; a criterion that is also identified as the prominent consideration in our analysis. The net influencers are '*Area of Study (Discipline)*', '*Audience for the Research*', '*Local and Institutional Culture*', '*Institutional Resources*', and '*Student's Prior Knowledge*'; these are the factors that influence more than they are being influenced by the rest of the criteria.

Fig. 1 illustrates the most notable interactions (the highlighted interactions in **bold** font) in the network of the curricular and pedagogical decision criteria; a misalignment here is likely to result in an underperforming curriculum.

The '*Students' role in the course*' has been found to be the central criterion with the greatest number of significant interactions; many criteria impose a meaningful impact on the students' role in research-based learning. This is natural considering how research-based learning questions the student's passive role in the old school education (i.e., being receptors of knowledge). This finding is in line with an

Table 3
Total relationship matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1	0,2693	0,3696	0,4155	0,3401	0,3592	0,4262	0,4274	**0,4587**	0,4433	**0,4628**	0,3671	0,1824
C2	0,3177	0,2682	0,3748	0,3140	0,3196	0,3949	0,4056	0,4180	0,4336	0,4223	0,3398	0,1498
C3	0,3264	0,3417	0,3261	0,3265	0,3352	0,4140	0,4321	0,4386	0,4440	**0,4567**	0,3533	0,1671
C4	0,3076	0,3505	0,4029	0,2722	0,3549	0,4131	0,4317	0,4342	0,4467	**0,4525**	0,3624	0,1675
C5	0,3322	0,3482	0,4073	0,3576	0,2753	0,4174	0,4254	0,4487	0,4406	0,4432	0,3529	0,1575
C6	0,3122	0,3443	0,3960	0,3256	0,3306	0,3355	0,4244	0,4443	0,4466	0,4455	0,3663	0,1808
C7	0,3189	0,3480	0,4073	0,3257	0,3307	0,4211	0,3479	0,4423	**0,4616**	**0,4639**	0,3666	0,1756
C8	0,3083	0,3475	0,3986	0,3292	0,3309	0,4121	0,4098	0,3513	**0,4519**	0,4438	0,3486	0,1611
C9	0,2949	0,3258	0,3813	0,3041	0,3058	0,3978	0,3985	0,4039	0,3381	0,4214	0,3301	0,1615
C10	0,3129	0,3422	0,4004	0,3372	0,3221	0,4004	0,4250	0,4478	**0,4507**	0,3615	0,3501	0,1655
C11	0,2957	0,3058	0,3757	0,3244	0,3261	0,3811	0,3923	0,3972	0,3985	0,4219	0,2673	0,1418
C12	0,3448	0,3529	0,3893	0,3068	0,2986	0,4177	0,4212	**0,4527**	0,4477	0,4462	0,3459	0,1365

Table 4
Prominence and net-causation analysis.

Criteria	Dispatched	Received	Prominence	Net-causation
C1	**4,5216**	3,7408	8,2623	0,7808
C2	4,1583	4,0447	8,2030	0,1136
C3	4,3618	4,6754	9,0371	-0,3136
C4	4,3963	3,8635	8,2597	0,5328
C5	4,4063	3,8891	8,2954	0,5172
C6	4,3521	4,8314	9,1835	-0,4794
C7	4,4095	4,9413	9,3508	-0,5318
C8	4,2931	5,1378	9,4309	-0,8447
C9	4,0632	5,2032	9,2664	-1,1400
C10	4,3158	**5,2416**	**9,5574**	-0,9258
C11	4,0279	4,1502	8,1781	-0,1223
C12	4,3604	1,9472	6,3076	2,4132

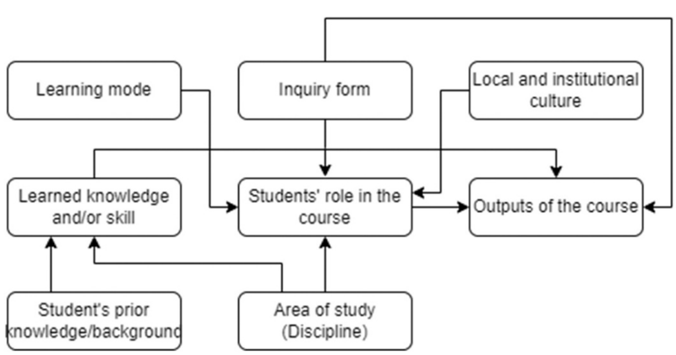

Fig. 1. Digraph of the decisive curricular and pedagogical decision criteria.

earlier study (Mick & Alan, 2009) suggesting that research-based learning emphasizes various forms of incorporating students as members of the research community.

5.2. Discussions

Results have several insights for the prospective research-based educator. Considering all the introduced criteria is important in developing a research-based course or program. As found in a systematic review and meta-analysis in higher education (Schneider & Preckel, 2017), carrying out a thorough organization of the learning design of a course by considering the various criteria is important. However, some criteria have a greater impact than others and hence require closer attention.

It is observed that three criteria have received the most above-threshold influences; Learned knowledge and/or skills, Outputs of the course, and Students' role. An important consideration in research-based learning will be what type of knowledge and skills students should gain from the course. Having a clear understanding of what is valued in terms of knowledge, skills, and output can therefore be a natural place to start in developing a research-based learning design from which a consideration of the criteria to achieve these can be considered (Reynolds & Kearns, 2017). The type of output from a research-based learning course (i.e., exams, presentations, and reports) has a special function as opposed to other learning approaches; courses based on research-based learning more explicitly open up for research publications as a product with utility both for learning the existing knowledge and development of new knowledge. The output expected at the end of a research-based learning course depends on many of the same criteria for the acquired knowledge and skills. Based on this finding, we suggest that considering what students should learn be prioritized upon which, reflections on output can be considered.

Local and institutional culture and institutional resources are two of the highest net influencers. It is, therefore, important to consider institutional resources and culture for implementing and carrying out research-based learning. Lack of resources and a supportive culture are oft-cited problems for researcher-teachers who argue for the benefits of research-based learning (Garde-Hansen & Calvert, 2007; Lambert, 2009). Changing such structural issues is not necessarily a small matter. However, the importance of considering such educational innovations as an extension of what is *already done* locally, culturally, and in terms of resources, can be a way to lessen the skepticism of modern learning approaches (Kopcha et al., 2016).

The student's prior knowledge plays an important role and has the greatest net cause. The importance of students' prior knowledge is well-known in the literature (Bransford et al., 1999; Dong et al., 2020). What is required in addition to being aware of students' prior knowledge is that educators connect what is to be learned with what students already know (Ambrose et al., 2010; Brod, 2021). This is done by starting at their current level and having a clear plan on how to develop the knowledge from there to the desired learning outcomes. Further, it should be understood that the disciplinary area of study, the modes of learning in the course, the concreteness of the inquiry, the form of inquiry, and the student's role in the research-based course will affect what knowledge and skills students will gain from the course. Therefore, as mentioned previously, thinking carefully about what kind of knowledge and skills are intended from the outset and taking as holistic a perspective as possible is an important prerequisite to developing the specifics of the research-based learning course.

The 'constructive alignment' and the 'ASSURE' model (Biggs, 1996; Kandlbinder, 2014; Kim & Downey, 2016; Lei, 2023) are some of the seminal learning design frameworks. An important critique of these frameworks is that they do not explicitly consider disciplinary, organizational culture, and institutional resources, and do not have a holistic view within an 'integrated course design' (Fink, 2013). Our findings emphasize that learning in general, and research-based learning in particular, should account for the role of contextual factors in the implementation of the design frameworks. Although several learning design frameworks suggest a specific progression in planning a course, it should be remembered that frameworks and models are simplifications of actual social processes. In individual educational contexts, there is a need for iteration of the learning design (Le-May Sheffield & Felten, 2018; Wynn & Eckert, 2017); an iterative learning design is necessary considering the many interacting criteria.

Overall, in order to implement research-based learning in an undergraduate course or program, the educator should (1) be aware of the introduced criteria and their interrelationships; (2) focus on the criteria with the greatest impact and the ones most influenced; and (3) take an *iterative* approach for the continuous improvement of the course/program. This approach provides a basis for embedding the new learning culture in a general sense and may require different or additional factors in accordance with institutional and program characteristics.

6. Concluding remarks

This study extended the literature on research-based learning design for undergraduate studies and is one of the few studies at the intersection of pedagogy and decision analysis in education. The findings offer insights into implementing research-based learning with a better understanding of the influential relationships that exist between the curricular/pedagogical decision criteria. This will help, among other things, to explain the success/failure of the study program in achieving the learning outcomes and improving the study program.

Q1. The following criteria were introduced as research-based learning design considerations: '*Area of Study (Discipline)*', '*The Audience for the Research*', '*Learning Mode*', '*Local and Institutional Culture*', '*Institutional Resources*', '*The Concreteness of the Inquiry*', '*Inquiry Form*', '*Learned Knowledge and/or Skill*', '*Outputs of the Course*', '*Students' Role in the Course*', '*Authority of the Decision-Maker*', and '*Student's Prior Knowledge*'.

Q2. Considering the interrelationships between the introduced curricular and pedagogical criteria, we found that '*Students' Role in the Course*' plays the central role in research-based learning; a criterion that features the highest level of interactions in the network of curricular and pedagogical decision criteria. This finding aligns with the literature indicating that students' learning of the knowledge improves to about eighty percent should they experience it. '*Student's Prior Knowledge*' is recognized as the net influencer that greatly influences the rest of the criteria but receives marginal influence. Finally, '*Outputs of the Course*', '*Students' Role in the Course*', and '*Learned Knowledge and/or Skill*' received the highest overall impact in the network, respectively, with 'Inquiry Form' being the top influencing criterion. This emphasizes that the curricular and pedagogical decision criteria introduced for research-based learning design determine the practical learning outcomes.

This study is limited in that inputs from Scandinavian universities are used to investigate the curricular and pedagogical decision criteria for research-based learning in undergraduate studies. Comparative studies can be conducted to evaluate research-based learning in other regions and educational environments. The findings of this study can be considered a steppingstone for deeper research in the field. In particular, future research may use multi-criteria decision-making (MCDM) methods for comparing the decision outcomes with and without the introduced considerations and in different educational contexts. Next, research-based learning in undergraduate studies is relatively new and requires deeper investigations and different perspectives on the subject. This includes studying the topic considering the implications of new technologies, like extended reality and generative AI that are expected to disrupt education and change its current shape and form. Finally, considering that few studies are conducted at the intersection of pedagogy and decision analysis, we think that DEMATEL analysis can be conducted in other educational contexts to structure decision problems, especially when the problem is relatively new or limited data is available.

CRediT authorship contribution statement

Isaksen K. Robert: Data curation, Investigation, Validation, Writing – review & editing. **Pourhejazy Pourya:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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