TAMÁS SNEIDER

Transdisciplinary Problem Solving: A new Approach for Validating Existing Literature

Abstract

The goal of this study is to present a model to validate pieces of literature in social studies that rely on the concept of transdisciplinarity. The study aims to answer the following question: how can researchers and practitioners validate existing transdisciplinary literature in social studies in an efficient and effective way? The method used in this paper is to build a conceptual model in a knowledge-based system (KBS), which is based on the if-then rules between the values of the attributes identified during the knowledge acquisition process. The model is first introduced and then it is applied to a set of papers incorporating transdisciplinarity in social studies. It is shown that with the help of the model, it is possible to efficiently and effectively validate the group of sample articles and assess their value in a potential transdisciplinary research project.

Keywords: transdisciplinarity, knowledge-based system, problem solving

INTRODUCTION

The goal of this paper is to present a conceptual model that is built in the Doctus knowledge-based expert system and serves to validate pieces of academic literature – journal articles, book chapters, conference papers – that incorporate and rely on the concept of transdisciplinarity.

Recent economic and social challenges require new approaches to problem solving, and transdisciplinarity is one of these new approaches. It is an emerging concept that started to draw more attention recently from academics, policymakers and other practitioners. However, transdisciplinarity is not a unified and universally well-defined concept, as there is an abundance of interpretations of transdisciplinarity, and for those who engage in some form of transdisciplinary research or problem solving, it is difficult to find the right conceptual foundations. Such researchers need tools to evaluate the different views and use-cases of transdisciplinarity that can be found in the literature. It is an important delineation of this paper that the focus is on social studies, and thus problems that belong entirely or mostly to the realm of the natural sciences are out of the scope of this paper.

In the first section of the paper the concept of transdisciplinarity is introduced. This is meant to be an introduction only, serving to provide context to the model that is going to follow. For a comprehensive review on the concept and applications

of transdisciplinarity, see for example Bernstein (2015). The second section introduces the tool that was used for model-building: the Doctus knowledge-based expert system. The model is described in detail in the third section, which is followed by discussing the novelty that is provided by this work, as well as its limitations.

1. TRANSDISCIPLINARITY

In social studies researchers are looking for tentative solutions to problems, as defined by Karl Popper (2002). This means that propositions are created and critically examined with an attempt to eliminate errors, and this leads to theories that in turn generate new problems. However, this does not mean that a problem can only have one solution in one discipline. A problem draws interest from many angles – for example unethical behavior in business can be observed from an economic, sociological, psychological, and several other perspectives. Such multifaceted problems have called for approaches that span over the boundaries of traditional academic disciplines. This can lead to multidisciplinary, interdisciplinary and transdisciplinary approaches. Several descriptions have been provided to differentiate between these approaches but the one that provides the most readily available understanding is a metaphor originally presented by Basarab Nicolescu and referenced by Baracskai and Dörfler (2017). In this metaphor disciplines are represented by birds in their cages. A mono-disciplinary approach is depicted by one bird in one cage. The single bird observes the problem space outside from its cage, and this results in a distorted and partial representation. However, this fact remains hidden for the bird inside the cage due to its lack of any meta-knowledge. Multidisciplinarity is represented by allowing more birds in their cages to observe the problem-space. The birds even communicate their observations to each other; however, this results in a complicated, but not complex view, as the songs of the birds are mostly incommensurable due to their different ontological, epistemological and methodological axioms. Interdisciplinarity arises when a bird is brought from its own cage to that of another bird. They share ideas, concepts and/or methods, and if the work is of high quality, the result can be meaningful knowledge creation that is more complex and less complicated. Still, the incommensurable aspects between the host and the guest bird may not be resolved and the limitation of the cage is still present. Transdisciplinary inquiry is represented by opening the cages and letting the birds fly outside. Most of them will probably choose to return to their cages, but some might learn songs from other birds perfectly and contribute to knowledge creation 'in the no man's land between cages'. Such knowledge can be fully complex without being complicated.

Transdisciplinary, thus, means not only going across but also going beyond disciplines (Klein, 2009). The concept was first used by Jean Piaget (1972), but it was later fully conceptualized by Basarab Nicolescu (2002). The conceptual framework of transdisciplinarity not only rests on the proposition of multiple levels of reality and the axiom of the included middle (Nicolescu, 2014), but it also inte-

grates the concepts of complexity (Cilliers–Nicolescu, 2012), knowledge integration (Hoffmann et al., 2017), and problem solving in the lifeworld (Hirsch Hadorn et al., 2008). Mono-disciplinary research looks only at one level of reality, where the axiom of the excluded middle holds, i.e., something cannot be 'A' and 'non-A' at the same time. Transdisciplinary research, on the other hand, can incorporate multiple levels of reality, and this allows for the possibility of what Nicolescu (2002) calls 'T', or the 'hidden third', that is the synthesis of 'A' and 'non-A'. This does not invalidate mono-disciplinary logic, only constrains its validity. This can be demonstrated with an example from physics: Newtonian physics worked well with the logic of the excluded middle but when it came to quantum physics and elementary particles, physicists realized that different logical rules applied there, since, using the terminology of Nicolescu, they were looking at a different level of reality. Social studies, in general, have not been doing so well in terms of overcoming a constrained, single-level view of reality. In this domain, there is still an overwhelming dominance of what Hayek has called scientism (Hayek, 1942), i.e., the imitation of the natural sciences through the use of tools and methods to create objective and detached knowledge. In contrast to this, a transdisciplinary approach to social inquiry acknowledges the inherent subjectivity of all phenomena that involve social entities, such as individuals, organizations, and societies.

Transdisciplinary approaches have been used to assess various societal questions and problems, such as climate change adaptation (Siebenhüner, 2018), urban development (Schauppenlehner-Kloyber–Penker, 2015), health equity in vulnerable communities (Reddy et al., 2018), responsible leadership in business (Gröschl–Gabaldon, 2018) and many others. Thus, those who engage in transdisciplinary inquiry can now find, – on top of the theoretical foundations – an abundance of applications and interpretations in the scientific literature. But how can researchers or practitioners validate these pieces in the available literature? A conceptual model for the validation is presented in the subsequent parts of this paper that is built on the use of the Doctus knowledge-based expert system. Before discussing the model, however, an introduction into knowledge-based systems, and specifically the tool used for building the model follows.

2. DOCTUS KNOWLEDGE-BASED EXPERT SYSTEM

The number of scholarly research articles was estimated to have passed 50 million in 2009 (Jinha, 2010) and it might have easily multiplied since then. Looking at the main concept of this paper, a search for the keywords 'transdisciplinarity' and 'transdisciplinary' on Google Scholar yielded 42,200 and 262,000 results respectively. Trying to read even a small fraction of these would not only be highly inefficient and impractical, but it is just humanly impossible. Anyone, therefore, who aims to acquire knowledge on transdisciplinarity from academic literature, needs to make key decisions on what to read. After narrowing down the scope of possibilities through the use of additional keywords or filtering for the date of

publication, it is likely that the researcher arrives to a set of articles that seem to meet the first criteria of what is worth at least looking into. After this point, it is largely based on the judgement of the individual researcher or the members of the research team, if the shortlisted articles are carefully read, cited in the output of the research, used in practical scenarios, and/or integrated into the transdisciplinary problem solving process. The key term here is judgement, and an important question is that how such judgement can be understood and supported. This is exactly what a knowledge-based expert system can do.

Supporting decisions with the help of computational tools has been around for a long time, but unlike typical operational research tools, expert systems support human reasoning instead of calculating a purely quantitative result (Velencei et al., 2014). The Doctus knowledge-based system (KBS) can be described as a form of artificial intelligence using 'if...then' rules to represent the symbolic knowledge of human experts. KBS is built on a shell, i.e., a software tool that allows humans to enter input, but its essence is the knowledge base of the human expert who uses the software to symbolize knowledge that is used in the decision-making process (Velencei et al., 2014). Baracskai et al. (2005) distinguish three types of decisions: (i) reflex decisions, where no deliberate thought process is present before making the decision; (ii) routine decisions that are repetitive and mostly follow programmable rules; and (iii) original decisions, where the circumstances are unique, and the decision is made based on complex cognitive schemata. Original decisions and even routine decisions to some extent require tacit knowledge (Polanyi, 1966) that cannot be expressed in explicit terms. The symbolic logic of the Doctus KBS remains very close to this nature of expert knowledge, as it does not force the user to quantify preferences. For example, a researcher can tell about an article whether its scope is narrow or broad without being able to assign numbers to this judgement. "Into the symbolic knowledge base of an expert system we can put the knowledge in form as we talk or think about it." (Baracskai et al., 2005, 61) This allows for transparency and the possibility of continuous fine-tuning.

How does the decision-making support work, if there is no quantification? How can the use of KBS add value to human deliberation? This happens through organizing expert knowledge into a systematic framework, eliminating potential contradictions, and getting rid of factors that turn out to be irrelevant. By creating a knowledge base, expert knowledge is organized into an explicit form. It is important to highlight, though, that this does not mean that tacit knowledge can be fully converted into explicit knowledge, as principally all human knowledge is rooted in the tacit dimension (Polanyi, 1966). Certain aspects of the expert knowledge are lost but this is a trade-off, which is required to be able to build up the deductive reasoning process in KBS. Through the knowledge acquisition process the 'if...then' rules are formulated (Baracskai et al., 2005), and any possible contradictions can be eliminated at this stage. One might think that experts are not prone to paradoxical and flawed thinking, but this is clearly not the case as discussed by Handy (1994), and therefore it is important to overcome this obstacle

during the preparation of the decision-making process. Finally, KBS can support the decision-maker by finding the criteria that are truly relevant for the decision. Initially, the decision-maker might have many attributes in mind that can influence the decision, but as the rules are built up, it is likely that several attributes become redundant and the set of relevant attributes is reduced, making the decision-making process more transparent and easier to reproduce, when needed.

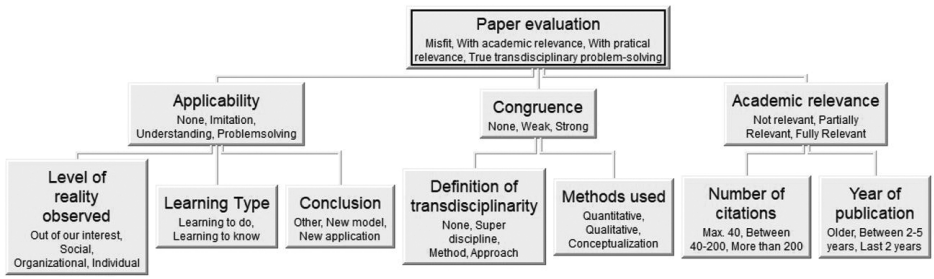
The Doctus KBS can be used to support business decisions, but it can also be used for supporting decisions in the transdisciplinary research process. An important novelty of this paper lies in presenting how this tool can be used to validate accessible knowledge on transdisciplinarity from academic literature. The next section describes how the conceptual model for this purpose was built in the Doctus KBS.

3. CONCEPTUAL MODEL

Creating a model in the Doctus KBS starts with setting up the attributes for rule-based reasoning. The attributes and the rules for this model were determined based on expert judgement with the goal of validating if a scholarly article can contribute to transdisciplinary problem-solving process. The expert judgments were gathered through personal discussions and an iterative process of documenting and continuously improving the model.

The three main pillars of the presented model are (1) applicability, (2) congruence and (3) academic relevance. Applicability describes how the knowledge acquired from an article can be applied in problem solving. Applicability is divided into three building blocks: (i) the level of reality observed (Nicolescu, 2014); (ii) the type of learning that can be achieved (Nicolescu, 2002); and (iii) the conclusion of the article. Congruence refers to how closely the contents of the article are matching the learning needs for the current project. It is comprised of (i) the definition of transdisciplinarity, and the (ii) research method that is used in the specific piece. Academic relevance looks at how accomplished the paper at hand is, and it is based on (i) the number of citations, and (ii) the year of publication. The three main judgment points lead to a final paper evaluation. The rule-based graph depicting these attributes in KBS are presented on figure 1.

Figure 1 Rule-based graph



Source: Own construction in Doctus KBS

The three main attributes and their component parts reflect the aspirations of the decision-maker (Velencei, 2019)"title":"New Human-Machine Relations Request a New Paradigm: Understanding Artificial Intelligence","type":"paper-conference"},"uris":["http://www.mendeley.com/documents/?uuid=37523a8b-ed5f-4ba7-a212-61831a0e4c0e"]}],"mendeley":{"formattedCitation":"(Velencei, 2019, in this case the researcher who is looking for valuable pieces in the literature. Based on how much they fulfil the aspirations, the attributes have outcome values that can be assigned to each article. When filling the knowledge base with content, the researcher assigns the values of all lowest level attributes, for example, if the conclusion of an article is (i) a new model; (ii) a new application of some existing model or tool; or (iii) something else, or if the methods used in the reported research project are (i) quantitative; (ii) qualitative; or (iii) a form of conceptualization. The values for the attributes are defined on an ordinal scale, for instance the number of citations is the least favourable, if it is not higher than 40, it is in the middle when between 40 and 200, and it is the most favourable when it is above 200. Some of the attributes are based on objective descriptive data, such as the year of publication, while others require judgments that contain a level of subjectivity (e.g., learning type); this is not only allowed, but necessary to reflect the process of human deliberation.

The values of the lower level attributes are then ordered to a set of rules that define the attributes on the next level. As discussed in the previous section, these rules are not quantified, but follow an 'if... then' logic. Verbally, such a rule can be defined as follows: 'If the paper defines transdisciplinarity as an approach and it presents a form of conceptualization, it is strongly congruent with the purposes of the transdisciplinary research project.' When all rules are defined on this level, another ruleset is defined to reach the values of paper evaluation. For example: 'If the applicability lies in imitation, there is a strong congruence, and the paper has partial academic relevance, the final paper evaluation will be that it provides practical relevance. Such rules are defined for all attributes in the Doctus KBS and

through the process of reduction (Baracskai et al., 2005), tables are created that visualize the logically purified ruleset for each aspiration. An example of this is shown in Table 1 through the rules of academic relevance.

Table 1 Rules of Academic Relevance

	Number of citations	Year of publication	Academic relevance
	Max. 40	.. Between 2-5 year	Not relevant
	Max. 40	Last 2 years	Partially Relevant
	Between 40-200	.. Between 2-5 year	Partially Relevant
	Between 40-200 ..	Last 2 years	Fully Relevant
	More than 200	*	Fully Relevant

Source: Own construction in Doctus KBS

The rows of the ruleset can be read as follows: If the number of citations is 'maximum 40' and the year of publication is 'between 2-5 years' old or worse (i.e., older than 5 years), the academic relevance of the paper is classified as 'not relevant'; if the number of citations is 'maximum 40' but the year of publication is 'last 2 years', then the article is 'partially relevant'; and so on.

To apply this model, a literature search has been conducted with the aim of finding relevant articles. Google Scholar and ScienceDirect databases have been used to search for the keywords 'transdisciplinary' and 'transdisciplinarity'. The year of publication was used as a filter to include only the results that have been published in the last ten years, as the aim was to evaluate contemporary works. Where it was possible, a filter was implied to search for articles in the domain of social studies and exclude natural sciences. Finally, 61 academic journal articles have been selected this way for the evaluation process. The data for the year of publication and the number citations was collected using Google Scholar, applicable as of September 2019. The abstract, the introduction and the conclusion sections of each article were read, and further sections or the complete papers were read where it was necessary to make a confident judgment for the remaining attributes.

After the data was entered into the Doctus KBS, and the deductive reasoning process was run, 11 articles came out as 'misfits'; 6 articles 'with academic relevance'; 32 articles 'with practical relevance'; and 12 articles as 'true transdisciplinary problem solving'. To illustrate the results, the values for two articles are shown on Table 2.

Table 2 Values assigned to the articles with the IDs 10 and 25

ID	Level of reality observed	Learning Type	Conclusion	Definition of transdisciplinarity	Methods used	Number of citations	Year of publication
10	Social	Learning to know	New model	Approach	Conceptualization	More than 200	Older
25	Organizational	Learning to do	New application	Approach	Conceptualization	Max. 40	Last 2 years

ID	Academic relevance	Applicability	Congruence	Paper evaluation
10	Fully Relevant	Understanding	Strong	With pratical relevance
25	Partially Relevant	Problem-solving	Strong	True transdisciplinary problemsolving

Source: Own construction in Doctus KBS

For the article with ID 10, the level of reality was judged to be 'social', the learning type as 'learning to know', the conclusion was a 'new model', transdisciplinarity was defined as an 'approach', 'conceptualization' was used as a method, it has been cited more than 200 times and was published more than 5 years ago. When applying the rules, it came out that this article was 'fully relevant' from an academic perspective, it had an applicability in 'understanding', and it showed 'strong' congruence with the learning needs for the research problem. As a result, the paper is evaluated as one 'with practical relevance'. Due to the different values of the lower level attributes, the paper with the ID 25 was 'partially relevant' from an academic perspective, it had an applicability in 'problem solving' and a strong 'congruence', thus it was evaluated as 'true transdisciplinary problem solving'.

4. DISCUSSION

Transdisciplinary problem solving is still relatively underutilized in social studies, but it is gaining popularity as more and more academic researchers realize that solving real life problems requires more than finding a gap in existing academic literature and designing a research project that fills that gap. Still, academic literature can provide help in guiding transdisciplinary inquiry but the inquirer needs to be conscious and selective about the added value of papers that rely on transdisciplinarity. The presented model should serve as a support in this process as it provides a new way of selecting and processing the available academic literature on transdisciplinarity. The novelty is provided not only through the new combination of elements to assess a transdisciplinary research report but also through the use of a knowledge-based expert system.

The use of KBS allows the inquirer to utilize their expert knowledge in an ordered and efficient manner. With this approach, human deliberation remains the most important process in reaching a decision or an evaluation, but the shell of KBS guides the expert through the elimination of potential contradictions and the reduction of logically unnecessary criteria. This paper has presented how a model was built and used for evaluating papers with rule-based reasoning, but the Doctus KBS also supports case-based reasoning, through which it is possible to find out the relevant aspirations of the decision-maker, once the decision outcomes are known (Baracskai et al., 2014).

As also highlighted earlier, the use of KBS system provides transparency and the possibility of continuous improvement. The presented model can be used 'as-is' by a researcher or a research team embarking on transdisciplinary problem-solving project, but it can also be customized, extended, or reduced to fit more specific purposes. Problem-solvers with very similar aspirations to those experts who were involved in the creation of this model might find it useful in this exact form, while others with different aspirations might wish to change some of the attributes, or add new ones. If researchers decide to set up different rules, they might receive different evaluations even for the same set of papers, but this is

natural as different aspirations can and should lead to different evaluations and decisions. This can all be supported with KBS and the approach of model-building that was presented in this paper.

For this reason, this paper may serve not only as a presentation of a new model in itself, but also as a guide for setting up similar models for evaluating academic literature for research projects in general. In order to build a model for the systematic and purposive evaluation of literature, one must start with a defined area of interest, such as transdisciplinarity in social studies, as in the case of the presented model. After this, the aspirations of the researcher or the research team need to be clarified and the attributes and rules in KBS need to be set up accordingly. The best source of this is expert knowledge, which, as discussed earlier, cannot be fully converted to explicit knowledge but it can be organized into a system of symbolic logical rules. This may happen through interviews, focus groups, workshops or brainstorming sessions. Once the initial model in KBS is set up, it should be tested on a sample of articles, similar to how the presented model was tested. The results need to be checked, together with the experts who were involved with building the model for the purpose of validation. The requirement at this stage is not that the evaluations fit the 'gut instincts' of the experts, but that they do not contain any contradictions. The size of the sample required for such a test can vary based on the chosen area of interest; it should be large enough to contain several of each of the final evaluation possibilities, but still practical enough to work with for testing purposes. For the case of transdisciplinary literature in social studies, 61 articles were deemed as a satisfactory sample size, in some cases it might be a somewhat less, while in other cases up to 100 articles may be more appropriate.

The limitations of the presented model and the approach also need to be addressed. The model is based on expert knowledge of several collaborators with experience from different fields and a solid conceptual understanding of transdisciplinarity. Although efforts were made to validate the findings, this type of inquiry inevitably leaves some room for human fallibility that may stem from individual factors, such as cognitive biases (Kahneman, 2011), or group level factors, such as groupthink (Janis, 1971). However, no scientific inquiry is completely devoid of these burdens, and the validation of the model relied on principles that are generally accepted in the scientific community, such as peer reviews. As for the approach that was presented, it can be applied flexibly, but also only with limitations. For example, if the number of attributes is greatly expanded and all or most of them remain relevant after building up the rules (e.g., several dozens) the required effort of assessing papers becomes very high, therefore the whole process might lose much of its efficiency. Just as with any other tool, trade-offs are required for optimal application.

5. CONCLUSION

This paper has presented a novel approach for validating existing pieces of transdisciplinary literature. Transdisciplinarity provides a new perspective for knowledge creation, and despite being outside of the mainstream academic approaches to research, a vast amount of literature has already been generated that build on the concept of transdisciplinary problem solving. Reading even a small fraction of this would be highly inefficient and impractical; therefore, those who aim to acquire knowledge on transdisciplinarity from the academic literature need to make key decisions on what to read and what to build on in their own research. The presented model, which was built with the use of the Doctus knowledge-based expert system, offers support in this process. The Doctus KBS is a form of artificial intelligence that uses 'if…then' rules to represent the symbolic knowledge of human experts. With this tool, it is possible to build a model that represents the aspirations and the decision making criteria of the researcher or research team, and with the help of such a model pieces of academic literature can be assessed and validated.

In this paper a specific model has been built, using the knowledge and expertise of experienced researchers. The attributes that were used in the model rely on foundational concepts of transdisciplinarity, such as the multiple levels of reality, as well as on highly practical measures, such the number of academic citations of an article. The logical rules connecting the attributes were described, as this provides the backbone of the validation process. With the help of the finalized model, it was possible to assess and validate 61 journal articles and decide if they were (i) misfits for a transdisciplinary study; (ii) if they had academic relevance; (iii) if they had practical relevance; (iv) or if they were applicable for true transdisciplinary problem solving. As a result of this, the literature review process can become more efficient and effective for a potential transdisciplinary research project.

The model can be applied in the form as it is described here, but perhaps more importantly, the approach that was used for building the model can be adopted and used as it fits best the purposes of any transdisciplinary problem-solving project. The method of using KBS for validating literature of any kind can be even further explored, but this is out of the scope of this paper. However, the description of the approach and the method that was used here might serve as a starting point for this further exploration.

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