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TOOLS AND METHODS TO EVALUATE EDUCATION FOR SUSTAINABILITY PROJECTS

Candidate: Francesco Loschiavo

Supervisor: Giulia Sonetti

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ABSTRACT

Education for sustainability (EfS) is a strong inter and transdisciplinary venue for scientists who are engaged in both complex problems (climate emergency, societal challenges, economic feasibility of projects, etc) and pedagogical approaches for making these problems understandable from a variety of points of view. The current EfS literature landscape is, in fact, made by a wide range of studies from different disciplines, each of them claiming for the efficacy of one methodology or tool that leads to a transformative process.

To assess the actual impact of researches and projects falling into the area of education for sustainability is still a very difficult task. A proper data analysis and a critical view on the content of such heterogeneous bulk of studies require an holistic approach, that has been well underpinned by the leverage point theory, aiming at finding "places in complex systems where relatively small changes can lead to potentially transformative systemic changes".

In this study, we performed a quantitative systematic review of empirical research addressing sustainability education actions. We used a modified version of Donella Meadows' notion of 'leverage points' to classify different actions according to their potential for system wide change and sustainability transformation.

We developed an algorithm that can indicate which type of interventions as presented in the literature is connected to research methods and problem framings tapping on 'deep leverage points' related to changing the system's rules, values and paradigms. The algorithm is coded in Python and it is integrated with a PRISMA analysis - a systematic approach to literature reviews – selecting for 563 articles claiming for transformative potential and containing keywords related to leverage points. 177 final articles were clustered according to four different disciplinary approaches. Our results are represented via a sankey diagram to show clarify all the steps of this process.

Taking into account methods and tools used in other articles with a similar classification purpose, a sensitive analysis was made to test the tool we used for this study. PRISMA analysis, thanks to the its flow diagram that the scribes every stage of the process, is clearer than other literature review methods. After adding the clustering algorithm, it resulted in a faster, but less accurate review. Add-on performing statistical analyses are both fast precise when using R as a coding software. The Sankey diagram, on the other hand, was the best in terms of clarity of representation and intuitively easy in its use.

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My greatest thanks go to professor Giulia Sonetti for inspiring me to do my best in the academic field, recognising my abilities and using them as most efficiently as possible. Thank you for involving me in a wide-ranging project, making me rediscover my love of knowledge. I would also like to thank Andrea Gerbaudo, my companion in this adventure in the Education for Sustainability.

And last but not least, I would like to thank my family who have paved the road I am travelled so far and who, I am sure, will continue to believe in me whatever the next path may be.

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1. INTRODUCTION

Modern problems require modern solutions. An increasing number of global sustainability crises need to be faced: climate change, overpopulation, CO2 emissions, energy transition, protecting biodiversity, urban development and mobility, water scarcity. Being able to adequately answer such a wide demand of questions is complex. Is it easy to identify which solution will be right for every issue? Well yes, but actually no. Sailing this sea can be frustrating, time consuming and confusing but some tools and methods may help other researchers.

Thus, the aim of this thesis is to identify instruments able to review and analyse sustainable processes proposed in papers and articles. This research stems from the necessity to provide technical support for the writing of a transdisciplinary, scientific paper called “Leverage points for Transformative Learning”. The purpose of that article is understanding which kind of intervention can be found in the Education for Sustainability (EfS) area. Despite the central role given to education for the sustainable development in UNESCO’s Agenda 2030(*Organizzazione Delle Nazioni Unite*, n.d.), a massive uncertainty still prevails in educational institutions, so the objective is to understand if most of the interventions that claim to be transformative match effective leverage points (LP) or not.

It is clear that, in the first stage, instruments will be listed and outlined. Secondly, examples will be presented to show how some of these are already applied. Thirdly, some questions will be proposed: how are these tools implemented in a given analysis? What is their correct purpose? Can any of them be improved? How? Answering these questions will be the focus of our discussion.

1.1. BACKGROUND

The call for sustainability projects has been constantly increasing in the last twenty years. To attempt to meet the demand, one of the most common strategy is to take action in education area, where different subjects collaborate to achieve a transformative intervention. Sustainability is indeed a complex system that can be processed only by breaking boundaries between disciplines.

Four disciplinary approaches are usually applied to EfS research:

- Monodisciplinary: involves a single academic discipline.
- Multidisciplinary: a linear combination of different disciplines that deal with a singular issue each from their own point of view. This approach aims to create a real picture of the investigation.
- Interdisciplinary: integrates different disciplines, their approach and their knowledge together. Assumption from one subject mutate to fit into others, creating new methodologies and solutions.
- Transdisciplinary: focuses on problems that cross subject boundaries. It aims to create a holistic system, where a constant exchange of methodologies, principles and technique is set up to facing research issues.

The tools that will be mentioned can be applied to every one of these approaches and to different kind of papers (case studies, researches, systematic reviews): they are general analysis instruments or methods created for a specific field and then used for other purposes.

A similar study was conducted in 2013 by Patric Brandt (Brandt et al., 2013). and their objective was to assess the scientific impact of sustainability researches and to allow transdisciplinary approach to be known and appreciated to the scientific community. They have listed many others tools and methods to analyse this type of investigations, therefore mentioning it is necessary to lay a solid foundation to this thesis. Nonetheless, tools that will be discussed were used in "Leverage points for sustainability transformation: a review on interventions in food and energy systems" (Dorninger et al., 2020). It is focused on understanding the type of interventions in the literature of sustainable transformation and how those interventions are applied and communicated through the leverage point theory. This analysis perspective implies taking a view on how transformation might happen and Dorninger's results highlight that interventions are partially driven by research methods and problem framing and that deep LP are rarely addressed. Methods used here fit perfectly with the evaluation of transformative learning for EfS, so it was natural to relate them to the writing of the new paper.

1.2. OBJECTIVES

The objectives of the thesis are:

- General objective:
  - Identify a methodology that could be applied to the largest number of papers with EfS as main topic, recognizing papers most relevant to the kind of research carried out.
- Specific objectives:
  - Try to make some of the processes involved easier/faster/more affordable than before, applying new tools able to support existing methods.

1.3. RESEARCH QUESTION

Starting from the aforementioned objectives, our question is:

Which tools and/or methods are needed to efficiently analyse sustainable processes proposed by EfS articles?

2. METHODOLOGY

This chapter presents how tools and methods mentioned above have been applied again on this new topic: Education for Sustainability. Specifically, we aim to evaluate interventions and whether they have transformative potential or not.

Going along with our reference text (Dorninger) is necessary to not misunderstand the role of each tool and to properly apply them. But, before starting this journey, it is necessary to talk about the articles collected. As the intent was investigating on EfS, our search string looks for papers that have "education", "sustainability", "trans-disciplinarity", "inter-disciplinarity", "multi-disciplinarity", and "cross-disciplinarity" in their title. The two databased were Scopus and ISI Web of Science. The focus was on education, so excluding every other subject was necessary. Only English articles and papers were taken into account.

2.1. METHODS

Mapping tools represents a starting point of this discussion while making them efficient and timesaving is our goal. It is necessary to note that the outcome represents a general overview that can be improved, using other instruments or paths. The exercise can be developed in many different ways: there are a lot of quantitative and qualitative methods of analysis.

However, as already mentioned, a similar investigation was carried out by Dorninger's team and we chose to use them as a model because the intention of our works was particularly similar. The instruments they used were applied to a new research on disciplinary approach related to transformative solution. In addition to the description of every tool, we will also mention how it has been made more accessible, more efficient, and/or faster than before.

Tools will be listed and examined in order of appearance on the reference paper.

2.1.1. PRISMA ANALYSIS (preferred reporting items for systematic reviews and meta-analysis)

The first step of every examination is the literature review. A systematic approach is needed to select and critically appraise relevant primary research, and extract and analyse data from the studies that are included in the review. It also collates all the knowledge on a given topic and it identifies the basis, assumptions, processes, and findings of that theme. Usually, a systematic review can provide data presented in the individual studies, with the aim of minimizing errors and being able to discuss the relevant conclusions.

The PRISMA analysis, in fact, is a set of items for reporting in systematic reviews that aim to evaluate the effects of interventions, but can also manage others outputs. Designed for studies on health, it is applied to mixed-methods of systematic reviews, but with previous consultation of guidelines addressing the presentation and synthesis of data (Page et al., 2021). It is made up of three instruments:

1. Abstract checklist: divided in 6 sections and 12 items, needed to evaluate abstracts.
2. Checklist: divided in 7 sections and 27 items, it is needed to analyse the full body of the articles.
3. Flow diagram: describes how the process works.

They fit the expectations associated with such tools: to be easily repeated and interpreted.

PRISMA helps authors to easily evaluate and hold or discard papers. It is composed of four phases:

a. Identification: corresponds to the collection of articles, papers and book chapters from at least two different sources. It is essential to look for the correct keywords, which must be specific to the area of study investigated, in the sources selected. It will also be necessary to delete all duplicates found in order to produce an appropriate database.
b. Screening: checking out information in the title, abstract and/or keywords. It is the first superficial stage of material selection which will provide a more precise and careful picking of articles.
c. Eligibility: the second stage of selection, it is done by reading the full text looking for inclusion criteria that must be clear and previously discussed and decided. It is important to understand that this is the key step in the whole process: setting inclusion criteria means placing a narrow destination and investigating in a very specific field of knowledge.
d. Included: finally, we obtain the total and true number of articles that will combine to create the starting database for future analysis.

These steps will be summarized in the PRISMA flow diagram.

The need to read article by article twice represents the biggest obstacle of this tools: it is very time-consuming. So, we tried to shorten the time frame by coding an algorithm in Python. The software consists of two parts:

1. The first that speeds up the screening phase by checking for keywords in the title.
2. The second that speeds up the eligibility phase by looking for other more specific words in the full text.

A function was coded for every step, and to help python to communicate with our files collected in PDF format, we defined another function able to convert them in text format. Lastly, the algorithm will print a list of suitable and eligible papers that will be read in their entirety for the final verdict.

2.1.2. AGGLOMERATIVE HIERARCHICAL CLUSTER ANALYSIS

Used to group objects (papers in our case) based on their similarity. At the beginning, every object is considered as a cluster by himself. They will be the leaf of the resulting tree: in fact, every similar pair of clusters will be merged into a node until all clusters are united into one: the root. The result is displayed in a dendrogram.

The Dorninger's team conducted this analysis using R software that needs a matrix where rows represent individuals and columns represent variables. Of course, to measure the similarity, a distance function is needed. It is calculated as Euclidean or Manhattan distance.

Furthermore, other functions are needed to identify clusters in a dataset:

1. Hclust function: performs a hierarchical cluster analysis using a set of dissimilarities for the objects being clustered. Iteratively, the algorithm allows the closest object to join in a branch. There are different clustering methods provided, the one used in the article analysed is the Ward's minimum variance methods that minimizes the total within-cluster variance. It is necessary to have a squared Euclidean distance to perform this method.
2. Agnes function: yields the agglomerative coefficient which measures the amount of clustering structure found, and provides another graphic display called banner in addition to the usual dendrogram.
3. Idval function: calculates the indicator value of species in types as the product of the relative frequency and relative average abundance in clusters.

We choose to use an Excel add-on called XLSTAT to facilitate the process, instead. It is indeed able to provide a similar result with the same input: a matrix of variables. To create it, we assign a score on a decimal scale for each aspect of the intervention analysed. XLSTAT is a flexible data analysis tool that allows users to easily do statistical investigation. It is also provided with graphical instrument, very useful to represent data obtained in a precise and immediate manner.

2.1.3. CHI-SQUARE TEST OF INDIPENDENCE

It determinates whether there is an association between categorical variables (if variables are independent or related). It is a non-parametric test that utilizes a contingency table to analyze the data. This table is an arrangement where data are classified according to at least two categorical variables which in their turn must include two groups at minimum. There are two set-ups for representing the starting data on a table:

1. Each row is a subject: occurs when you have the raw data. Each subjects appears once in the dataset and each row represents an observation from a unique subject.
2. Each row is a combination of factors: occurs when you have frequencies. The frequency is the number of unique subjects with that combination of categories. With this dataset, at least three variables are needed: one representing each category, a second and a third representing the number of occurrences of that particular combination of factors.

2.1.4. LEVERAGE POINTS

A place within a complex system where a shift in one thing can produce big changes in everything. Knowing where they can be found is necessary to understand what led to said change. There is a hierarchy of 12 places where to intervene in a system. From the most to the least effective, they are:

1. The power to transcend paradigms.
2. The mindset or paradigms out of which the system arises.
3. The goals of the system.
4. The power to add, change, evolve, or self-organize system structure.
5. The rules of the system.

6. The structure of information flows.

7. The gain around driving positive feedback loops.

8. The strength of negative system loops.

9. The lengths of delays, relative to the rate of system change.

10. The structure of material stocks and flows.

11. The sizes of buffer and other stabilizing stocks, relative to their flows.

12. Constants, parameters, numbers.

Donella Meadows (Meadows, n.d.) developed this method in 1999 and in 2017 it was picked up by Abson (Abson et al., 2017) that synthesized the 12 original leverage points into four broad system characteristics on which intervention can be focused: parameters (taxes, standards, buffers, flows), feedback (positive or negative), design (information flow) and intent (goals, paradigms, mindset). This tool can be modelled according to the topic analyzed. At first, it must be clearly defined what is meant by intervention in order to identify if there it is or not, and to not misjudge the correct LP.

In order to apply the to a specific and new topic, these leverage points have been transferred and modified according to our needs. Adapt them to transformative learning issue was not difficult because they are a very flexible tool.

2.1.5. SANKEY DIAGRAM

It is a visualization technique that aims to illustrate connections between different variable categories. It is used to visualize a wide range of flow (energy accounts, material, cost breakdowns, information, process engineering, process control, supply chain) and emphasize the major transfers within a system. It helps locate the most important contributions to a flow. In fact, it is used to show weighted networks: the larger the width of a narrow, the larger the flow. As for every visualization tool, the position of nodes is very important: the directed flow is always drawn between at least two of them. Thus, it shows not only flow values but also structure and distribution of the defined system. This can not be achieved through standard table, pie or bar charts. So, a Sankey diagram communicate the message better than every other visual tool. There are different kind of Sankey based on what they need to explain.

The software used was e!sankey, the leading program for drawing this kind of diagram. It is very simple to use, but, as for every graphical tool like this, a solid clear database is needed.

2.2. LIMITATIONS

It is clear that choosing an article of reference will lead to the necessary use of the same approach and instruments. Their application in a different field may have distorted something: of course, we had to decline them to our purpose.

The information provided is strictly related to our database of papers and deeply dependent on the objectives set, the route taken is not intended as the right one or the only one. The investigation can still be carried out by experimenting other tools and trying to make their operation s even more accessible.

In particular, the algorithm created as a support for the PRISMA led to a thorough reading of some articles. Imagine instead if the systematic review could be completely conducted by an artificial intelligence capable of probing and understanding every text, and extracting data from them. It would be easier, faster and more precise. Unfortunately, algorithms like that require years of study combined with very aware and deep coding skills.

4. RESULTS

In order to present the results of our implementations, it will be necessary to show some parts of the algorithm, diagram, graphs and tables and compare them with those of the previously mentioned studies. Obviously, the contrast will mark differences and similarities of distinct approaches. Moreover, all these graphical instruments allow clarity of presentation and an immediate understanding of the results.

As it might be easy to go astray, we will recall that the proposed results are not related to those obtained for the drafting of the article on leverage points for sustainability. Those results will be integrated in the final paragraph of this chapter because it is dedicated to the tool used for representing them. Hereafter indeed the general output provided will be explained and simplified.

4.1. PRISMA AND PYTHON

Both in Dorninger and in our papers, PRISMA provides a resume diagram. Both will have the exact same graphical output, but the routes to obtain it are different except for the identification step. In fact, we built an algorithm that would take us directly to the final eligibility stage.

Starting from 11906 papers, Dorninger's team applied their exclusion criteria screening title, abstract and keywords. They specifically looked for empirical papers that report an explicit intervention with sustainability change as target in food and energy system of interest or that formulates possible interventions based on the empirical observation. Thus, descriptive studies without intervention proposed were excluded from the review. Then, they applied again those criteria to the full-text eligibility assessment, obtaining the final pool of papers (301).

It was decided to build an algorithm that would speed up this process. Before we start describing the algorithm, it is necessary to describe our inclusion criteria: to ensure focus on transformative learning we choose to look for keywords (checked in the title) of this area: education, learning, school, teaching, university. And, for the eligibility stage, we look for keywords related to a real intervention: case study, intervention, solution. Now, let's have a look at the algorithm.

In the screening stage, we employ a function called "conversione_e_controllo_parole_titolo". It consists of two nested "for" cycle to scan every file title, acquired thanks to a function of the Glob library. The outer loop flows the files while the inner one flows the keywords we are searching. As python can not properly communicate with PDF file format, a function was implemented to translate them in text format. In chronological order the function:

1. Reads the file name.
2. Saves it as a string.
3. Checks if the string matches the title of an already existing text file using the path function from OS library, already available in Python. This check was made for ensure to have no duplicates in text files.
4. Create a new file, identical to the PDF one, but with text format to? Non sono sicuro di cosa volessi dire go along to the next PDF file. An external library called PDFminer has been employed to achieve this result.
5. Names it as the previously saved string.
6. Saves the new file in a folder.

To accomplish the eligibility phase, the two nested "for" scheme has been reutilised in a function called "controllo_parole_testo". The first loop will open one file at a time and save the full body in a temporary variable; the second one will select one word at a time from our second list and will look for that in the variable. Subsequently, a function from the Pandas library allows us to set up a data-frame where every word we searched is printed on a column and the file names will populate the rows. Finally, thanks to the Xlsxwriter, the algorithm can locate the data-frame in an Excel file that is easier to read than the Python output. Moreover, in the final dialogue box, every paper that does not meet the selection criteria were displayed.

However, a final reading of the articles presented in the excel file was necessary: the algorithm is not able to understand which articles fit perfectly within our research and can not extrapolate data needed for future analysis.

The final result is shown in the flow diagram below (*Figure 1*).

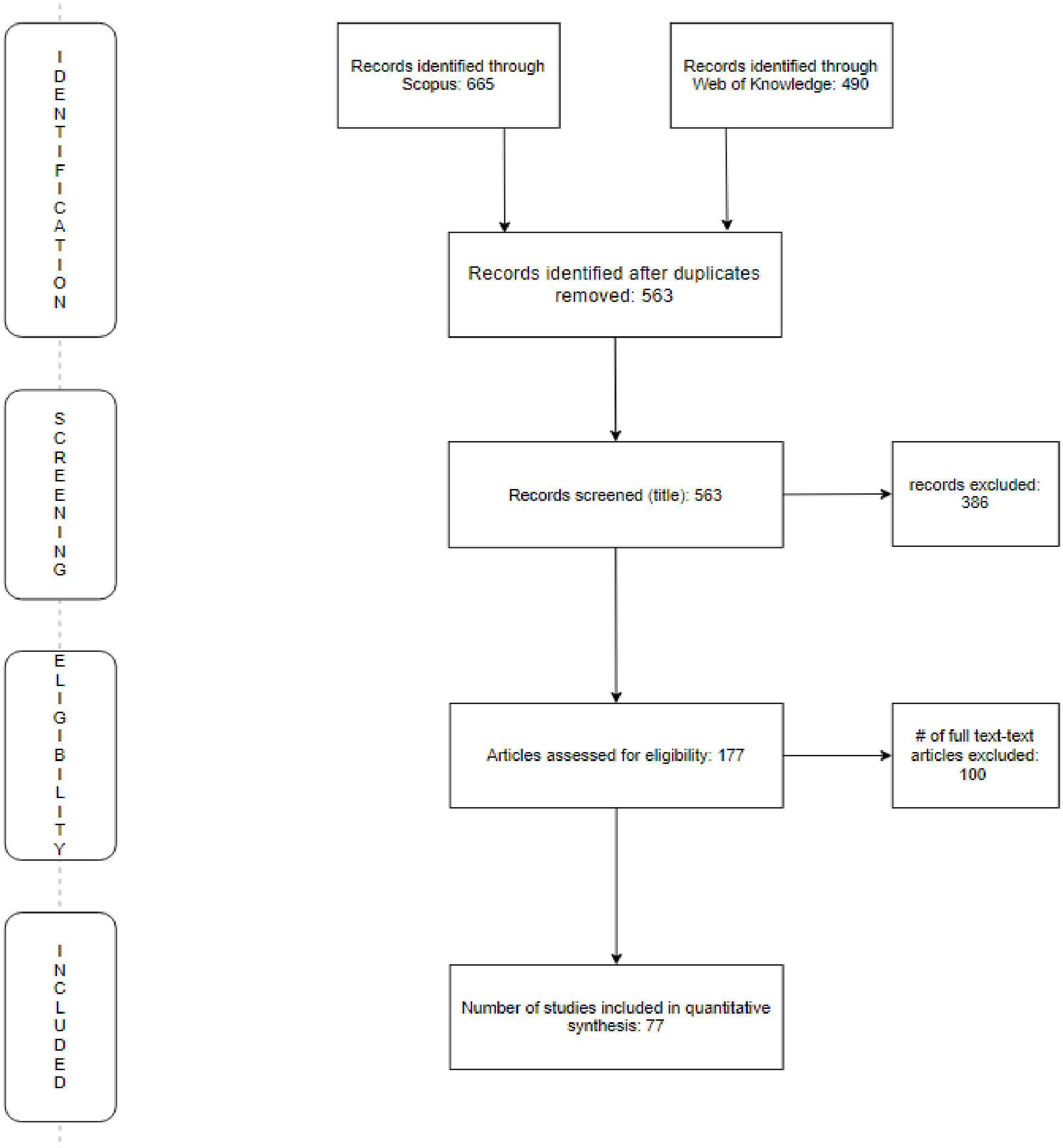


Figure 1

4.2. CLUSTER AND XLSTAT

While in the referenced article the path chosen for the cluster analysis has been the classic one (already described in paragraph 2.1.2), we looked for a tool that would allow to skip the whole coding part. We used an add-on for excel called XLSTAT that is a really useful and powerful instrument. Thanks to the previous analysis (PRISMA) the correct number of articles was found and analysed, and a good pool of data wase collected. Every piece of data was transformed into a decimal value, including qualitative data. Thus, the add-on was able to extrapolate all the necessary information.

The analysis provides four different clusters as it is easily understandable by looking at the dendrogram provided by XLSTAT (Figure 2).

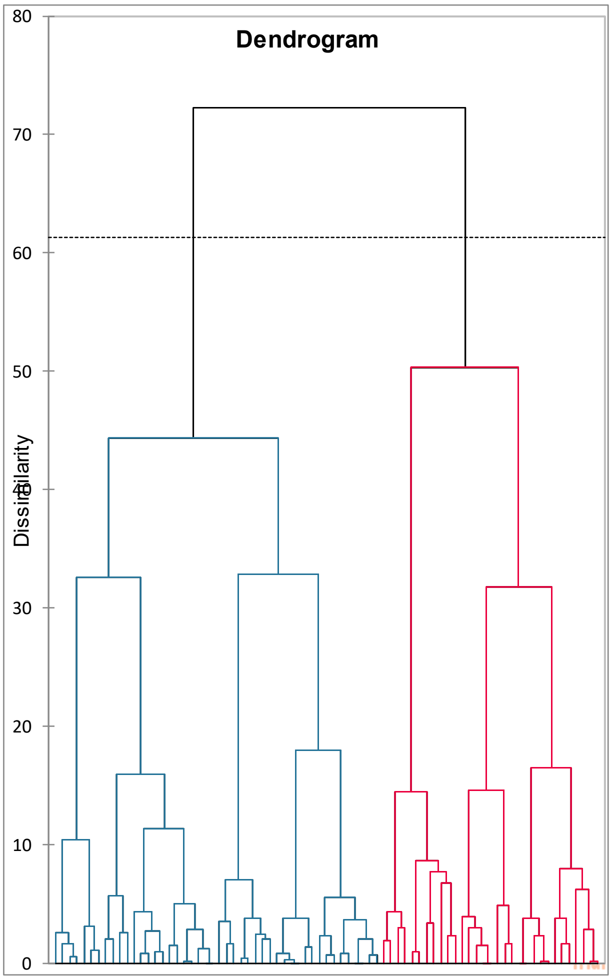


Figure 2

In fact, the four clusters founded are clearly visible. Each one represents a different disciplinary approach and includes those introduced in paragraph 1.1.

Thanks to crosse-checked data between the clusters and our dataset, we are able to assign specific characteristics to every different class of approach.

Instead, in *Figure 3* it is possible to check how many papers have been produced per year according to their category. We can see the trend (based on linear regression function also performed with XLSTAT) of their publication as well.

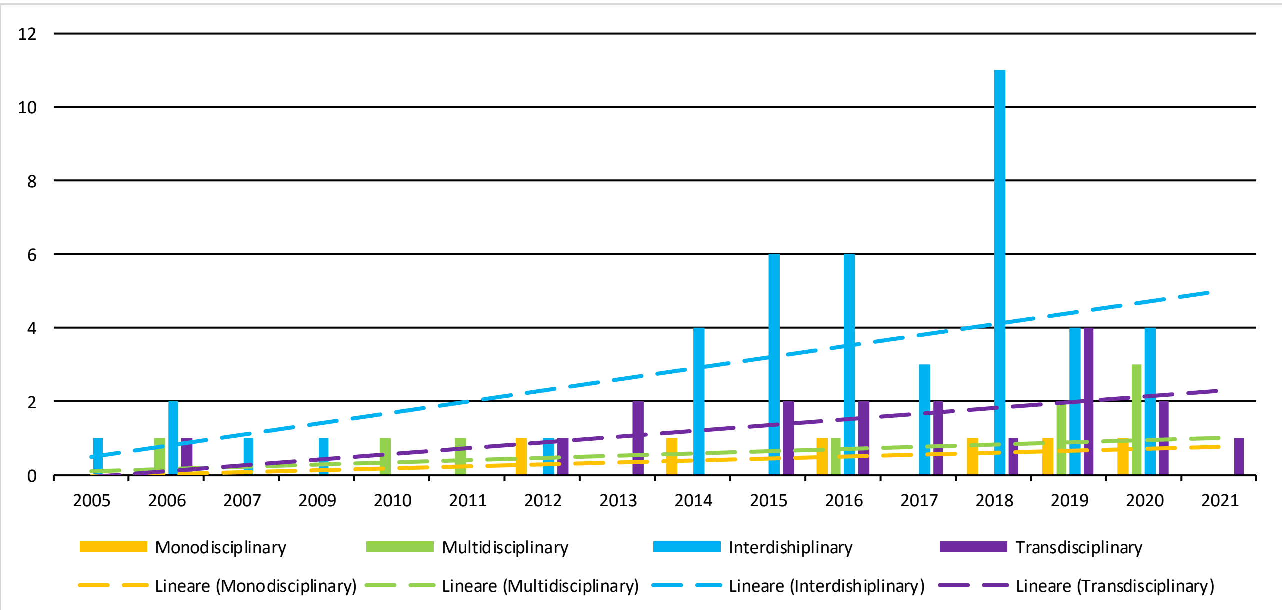


Figure 3

4.3. LEVERAGE POINT AND THEIR FLEXIBILITY

One of the best features of the Donella Medow's theory is its flexibility. Leverage points indeed can be applied to every argument, provided that the aim of the analysis is to study changes in a reference system. Thus, to get the most out of this tool, we translated them so that they could easily interface with EfS and transformative learning. In *Table 1* leverage points are listed in increasing order of effectiveness and translated according to our purpose.

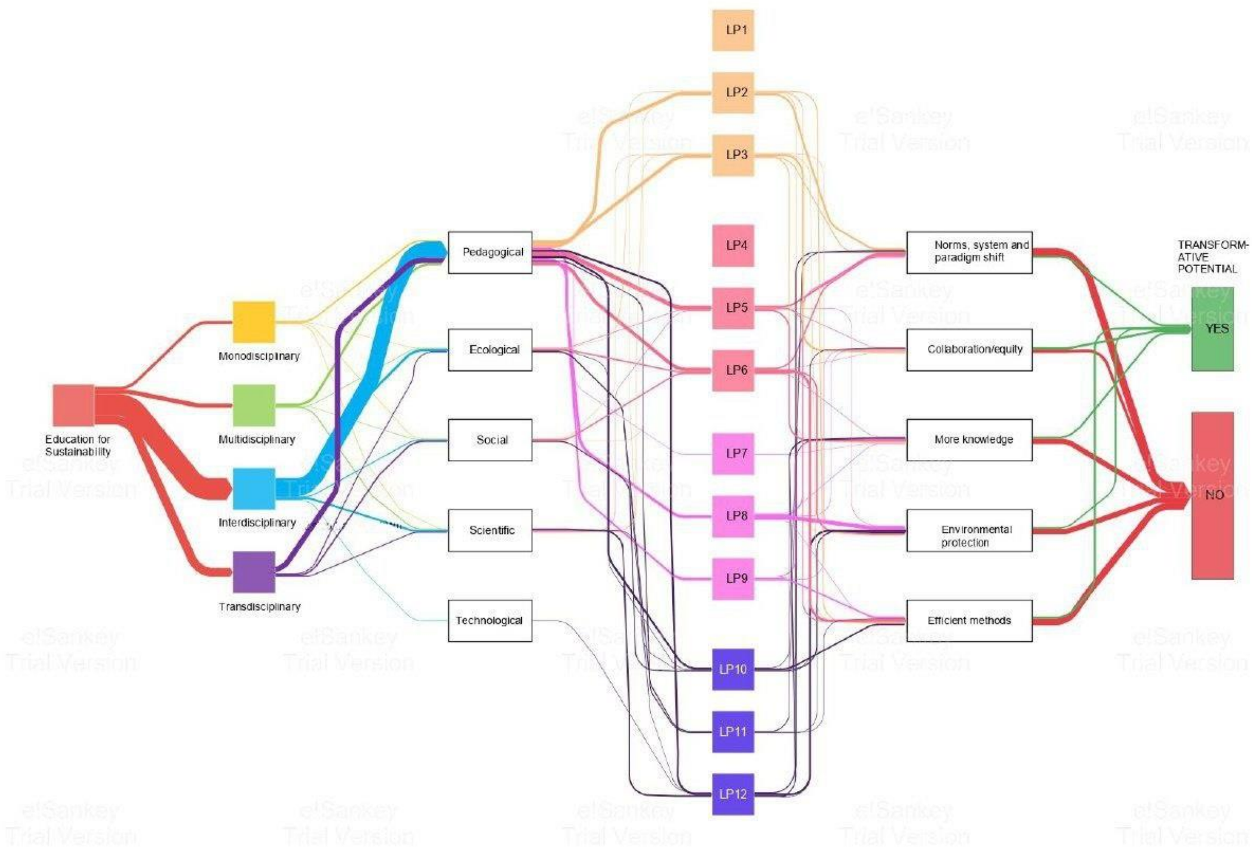
	Meadows (1999) places to intervene in a system	Leverage point for transformative learning (2021)
12	Constants, parameters, numbers (such as subsidies, taxes, standards)	Interventions that aim to change number of courses, workshops, curricula for EfS
11	The sizes of buffers and other stabilizing stocks, relative to their flows	Interventions that aim to create a stable share of EfS projects
10	The structure of material stocks and flows (such as transport networks, population age structures)	Physical changes in the structure of universities or offices
9	The length of delays, relative to the rate of system change	Interventions that aim to get feedback faster than the standard timeframe
8	The strength of negative feedback loops, relative to the impacts they are trying to correct against	Self-correction of the system or emergency response mechanism
7	The gain around driving positive feedback loops	Advice for too fast transition on EfS (too enthusiasm can lead to wrong feedback)
6	The structure of information flows (who does and does not have access to what kinds of information)	The structure of information flows (that clarify results of intervention)
5	The rules of the system (such as incentives, punishments, constraints)	The rules of the system (such as evaluation, recruitment criteria of teachers, examination methods)
4	The power to add, change, evolve, or self-organize system structure	The power of self-organization, in order to make the system resilient
3	The goal of the system	The goal of the system
2	The mindset or paradigm out of which the system - its goals, structure, rules, delays, parameters - arises	The mindset or paradigm out of which the system - its goals, structure, rules, delays, parameters - arises
1	The power to transcend paradigms	The power to transcend paradigms (no Paradigms needed, extreme flexibility of the system)

Figure 4

4.4. SANKEY DIAGRAM AND FINAL RESULTS

At the end, it was necessary to make relationships between all the variables clear so that the results could be easily represented. Thus, the Sankey diagram was built. And, as mentioned in the introduction of this chapter, some results of the study conducted will be shared here.

Interdisciplinary approach is the most represented (it counts the 57% of total papers), followed by transdisciplinarity, which shows a significant growth trend during years. Very few papers utilise a multidisciplinary approach and only one faces problems looking at just one subject. As expected, acting in the education area, the most common problem framing analysed was the pedagogical one and it touches deep leverage points (from 2 to 6), leading to change in system's intent. Meanwhile, ecological and social framings show relation with less effective LP (from 10 to 12). No article was able to address the problems analysed in the most efficient and effective way: by transcending paradigms and by modelling paradigms based on the requirements. However, the most interesting results obtained was at the end of the Sankey Diagram. In fact, it is possible to see how a very small number of papers clearly talk about the transformative potential of the solution proposed.



5. DISCUSSION

Unsolved sustainability issues are a widely discussed topic by the scientific community. The need for a clear list of instruments to analyse these problems must be met. This thesis offers a good example of how different tools can be used to achieve the goal.

In fact, the results previously listed show us how the methods applied are advanced, precise and intuitive, even though they often took unconventional routes. Moreover, these methods proved to be flexible and adaptable not only to various topics, but also to structural changes such as introduction of algorithm, unusual tools and revisiting of intensions. Therefore, they are considered as excellent tools for the analysis of sustainability-oriented articles, regardless of time and writer's background and skills. The parent paper was written by a multidisciplinary team, indeed.

However, these instruments have their limitations and others, with the same purpose, can be applied.

Take the systematic literature review for example. We have stated that the first stage of PRISMA usually analyses title, abstract and keywords of papers. Experimenting with coding skills applied to this new problem, the program written in Python helped to speed up the process, whereas the algorithm takes in to account titles only: this is because it was necessary to make the algorithm more compact, more efficient and faster. In fact, to translate every single file into a txt format, without a previous selection, would have been very long and time consuming. The transformation from one format to another was anyway indispensable, as Python has great difficulty working with PDF files that are very complex because they may describe text, images and diagram at any resolution, and table all in one. Moreover, to complete the eligibility phase, it was necessary to read the selected papers both to check if the algorithm had done its job correctly, and to extrapolate the required data, despite the program coded. Even with today's technology, it would be extremely difficult to write an algorithm capable of understanding texts and analysing data proposed therein. The future of scientific analysis probably lies in artificial intelligence and its various application.

But, coming back to the present, it can be seen in Brandt's paper that, for a similar investigation, different methods were applied not only for the literature review but also for grouping articles into descriptive sets. It is useful to remember that they were looking for the development of a broad common suit of appropriate methods for transdisciplinary papers. Furthermore, they used as example a paper from Newig and Fritsch (Newig & Fritsch, n.d.) which research aims to collect and review existing application of case-study methods in political science. This shows that Brandt et al. have also used methods from a different topic and so their instruments were flexible and adaptable as ours.

About the literature review, they choose to collect articles from one database and to apply two consequent inclusion criteria:

1. If the case study takes into account two different subjects as well as practitioners outside academia, the article will pass to the next step.
2. To be eligible the article must contain the term "sustainability science".

Then, the remaining articles will be double checked and categorised. This method, although similar to ours, is slower and less schematic because it does not use any tools to summarise the process. However, sorting articles in this phase will make the cluster analysis easier. In fact, every paper was classified based on transdisciplinary fundamental components:

a) Process phases.
b) Knowledge type
c) Intensity of involvement of non-scientists.

Then, they use R software to verify relations within the data and they test those relationships with chi-square tests for significance. In this way, they will get a pre-addressed but nevertheless precise analysis.

Therefore, as we have seen, there are many methods and tools, and all of them have their own merits and weakness. It is recommended to study a large number of them before choosing one and applying it. Creating a standard to analyse sustainability papers, would be a complex challenge, but this thesis can be a good starting point.

6. CONCLUSION

Education for sustainability (EfS) is a strong inter and transdisciplinary venue for scientists who are engaged in both complex problems (climate emergency, societal challenges, economic feasibility of projects, etc) and pedagogical approaches for making these problems understandable from a variety of points of view. The current EfS literature landscape is, in fact, made by a wide range of studies from different disciplines, each of them claiming for the efficacy of one methodology or tool that leads to a transformative process.

To assess the actual impact of researches and projects falling into the area of education for sustainability is still a very difficult task. A proper data analysis and a critical view on the content of such heterogeneous bulk of studies require an holistic approach, that has been well underpinned by the leverage point theory, aiming at finding “places in complex systems where relatively small changes can lead to potentially transformative systemic changes”.

In this study, we performed a quantitative systematic review of empirical research addressing sustainability education actions. We used a modified version of Donella Meadows' notion of ‘leverage points’ to classify different actions according to their potential for system wide change and sustainability transformation.

We developed an algorithm that can indicate which type of interventions as presented in the literature is connected to research methods and problem framings tapping on ‘deep leverage points’ related to changing the system's rules, values and paradigms. The algorithm is coded in Python and it is integrated with a PRISMA analysis - a systematic approach to literature reviews – selecting for 563 articles claiming for transformative potential and containing keywords related to leverage points. 177 final articles were clustered according to four different disciplinary approaches. Our results are represented via a sankey diagram to show clarify all the steps of this process.

Taking into account methods and tools used in other articles with a similar classifica tion purpose, a sensitive analysis was made to test the tool we used for this study. PRISMA analysis, thanks to the its flow diagram that the scribes every stage of the process, is clearer than other literature review methods. After adding the clustering algorithm, it resulted in a faster, but less accurate review. Add-on performing statistical analyses are both fast precise when using R as a coding software. The Sankey diagram, on the other hand, was the best in terms of clarity of representation and intui tively easy in its use.

In order to understand characteristics and aims of each article, two tools were applied. Cluster analysis grouped articles in four sets, thanks to an add-on for Excel. This tool made the analysis simpler than every other performed in similar papers: in fact, it is only needed to collect data from papers, assign a decimal value to them, and store them into a matrix. The add-on does the rest, showing the dendrogram and thus all groups and their characteristics. On the contrary, the tool that is usually applied to this type of analysis is the R software, which, however, requires previous knowledge and much more time to achieve a similar result.

Eventually, the Sankey diagram has been employed to show and make a clear visual representation of the data collected and analysed. It is very simple to build it, and the Sankey software has been found to be very user-friendly, as it only needs a good dataset to start from.

Sustainability issues society currently faces are so dramatic that education must place them as a priority and prepare students to face them. To do so, in addition to knowledge co-production on these topics, interdisciplinary research approaches and tools are essential to understand the effective transformative potential of projects. The present study contributes to the scouting of effective tools and approaches to evaluate the transformative potential of projects claiming to tackle current sustainability challenges.

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