

## Article

# Impact of Student Interventions on Urban Greening Processes

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**Abstract:** The aim of this study is to determine the contribution of student interventions to urban greening processes. In two Dutch cities action research was conducted, including reflexive interviews a year after the first intervention, to assess factors causing change in the socio-ecological system. Results show that students and network actors were mutually learning, causing the empowerment of actors in that network by adding contextualized knowledge, enlarging the social network, expanding the amount of interactions in the socio-ecological system and speeding up the process. Students brought unique qualities to the process: time, access to stakeholders who tend to distrust the municipality and a certain open-mindedness. Their mere presence made a difference and started a process of change. However, university staff needed to keep the focus on long-term effects and empowerment, because students did not oversee that. After a year, many new green elements had been developed or were in the planning phase. In Enschede, the municipality district managers were part of the learning network, which made it easier to cause changes in the main ecological network. In Haarlem however, no change took place in the main ecological network managed by the municipality, because no political empowerment of the civil society group had developed yet.

**Keywords:** socio-ecological system; empowerment; green city; student intervention; learning networks; action research

## 1. Introduction

### 1.1. Greening the City

In October 2019, a downpour caused pedestrians and cyclists to wade to their knees through the water in Haarlem North (The Netherlands). This part of the city is very paved, so the water could not drain properly. Although no major accidents occurred, this event has reinforced the call for change. This relatively small incident does not stand alone. In many cities the paved surface increases due to infill and urban expansion. In addition, climate change makes the city's climate warmer and causes more and more peak showers. As a result of this, the liveability of cities will decrease (for a detailed description of this problem, see the introduction to this special issue). A green infrastructure can help solve these problems [1–6]. However, a green infrastructure in cities is often contested or even last in line, due to a lack of space or competition with one-dimensional functions yielding direct money, like transport, retail and industry. In addition, a green infrastructure may cause hindrance to individuals, such as the shadow cast by the trees, leaves in front of the door or sticky matter from the trees on car roofs. In contrast, the benefits for the community—green infrastructure ecosystem services—are more diffuse and not immediately visible to most citizens.

Actors that can see the bigger picture are committed to strengthening the green infrastructure, sometimes with a quick result. However, the initiatives might also get stuck due to resistance, rules or procedures [7]. In the latter case, it is not easy to maintain enthusiasm and continue. An intervention

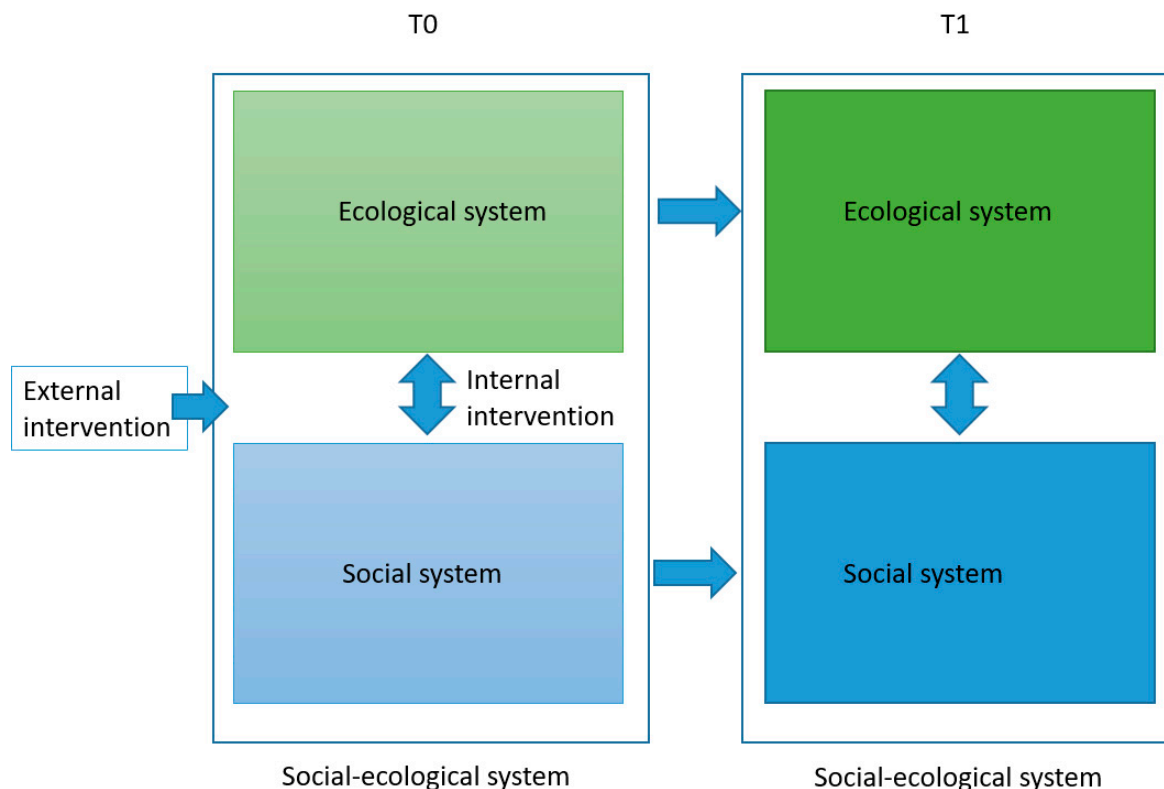
from outside can then be helpful. Knowledge is added to the process, the urgency can be clarified, and sometimes it takes a fresh pair of eyes to put things into proper perspective [8]. Interventions can take place through contributions by specialized organizations, such as Science Shops [9] and Heidemaatschappij (A Dutch non-profit organization aiding civil society groups), but also through the efforts of students.

Worldwide universities have three missions: education, research and social responsibility [10]. Students can contribute to the third mission in different ways, e.g., by doing research and making plans for local actors or civil society organizations. Forester [11] described this third mission from a university perspective as participatory action research. Tejedó et al. [12] described the different ways in which higher education can contribute to solving societal problems. Not just learning for learning, but also contributing to society and at the same time learning skills that can only be learned in real-life situations. Although the potential positive effects for education are clear, the effects on urban greening have not yet been researched in depth. Therefore the aim of this study is to determine the contribution of student interventions in urban greening processes.

### *1.2. Changing the Socio-Ecological System*

We used the socio-ecological system framework as our theoretical starting point [13]. This framework describes all potentially relevant factors in the relation between the social and ecological world (Appendix A, Table A1). The core subsystems in the framework are resource system(s), resource units, actors and governance system(s). These core subsystems all interact together in order to create outcomes that feed back to the subsystems and also impact other related ecosystems outside of the socio-ecological system [14]. The system is inherently open: influences to and from other ecosystems or social, economic and political settings can affect any of its components [13]. As Hawe et al. [15] and Moore et al. [16] stated, a good overview of the system is needed before an intervention can take place. As such, the socio-ecological system is a good starting point for designing an intervention and for assessing its effects. This intervention changes the system from the current situation (T0) into another—more acceptable—situation (T1) (see Figure 1). Hawe et al. [15] described it as follows (for an intervention in the health system): “An intervention may then be seen as a critical event in the history of a system, leading to the evolution of new structures of interaction and new shared meanings. Interventions impact on evolving networks of person-time-place interaction, changing relationships, displacing existing activities and redistributing and transforming resources.”

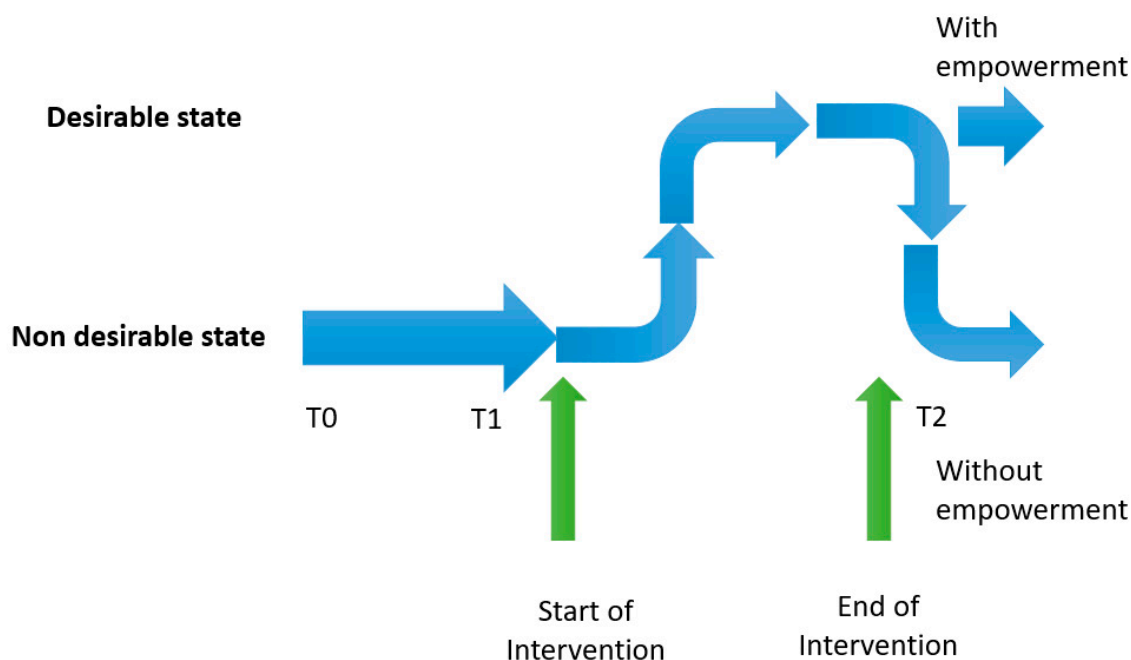
This change can come from inside the system (internal intervention) or from outside the system (external intervention). Internal interventions come from the social system and influence either the social system itself or the ecological system. External interventions can be ecological, as the example of the flooding of Haarlem shows, but in our study we focus on social external interventions, which means that agents from outside enter the system. These interventions can have an effect on, or at least make proposals for, change in one or both the subsystems. In order to make the change lasting, effective empowerment should take place (see next section).



**Figure 1.** Interventions in the socio-ecological system.

Almost all literature on external interventions is about medical interventions (on AIDS, Alzheimer, smoking, etc.), which are basically all interventions in the social system alone. Although Buijs et al. [17] wrote about interventions in the green infrastructure of cities, they meant internal interventions (see Figure 1) in the socio-ecological system. This is the effect of the intervention from civil society organizations on the green space in the local system. Schäfer et al. [18] are among the few that write about external interventions for sustainability (lowering carbon emission). They argue that top-down interventions often focus on knowledge transfer to individuals, while real changes need a shift in governance: “intentional communities base their interventions on the collective creation of shared visions, decisions, and rules and thus provide social and material structures, which foster everyday low-carbon practices and discourage carbon-intensive ones.” Two things stand out here: first, the described aspects can be found in the ecological systems framework used in this paper; second, in order to gain “real change”, the system should change in such a way that empowerment occurs. As Rocha [19] and Fraser et al. [20] stated, empowerment is increasing the capacity in economic, social, psychological and political terms to shape one’s own living environment. An addition to this definition should be that empowerment also implies the capacity *to maintain* the desired outcome, which, according to Dempsey and Burton [21] and Burton et al. [22], is even more difficult.

Empowerment is thus necessary to make changes durable (long-lasting). In the process of change, the local stakeholders should develop skills that are necessary to keep the changed settings of the socio-ecological system in place (Figure 2). This applies to both the ecological component (management, monitoring) and the social component of the system (governance, networking, etc.). In our case, the student projects are the intervention in the local process of change.



**Figure 2.** Possible development paths after an intervention (based on [8], p. 19).

To increase the above-mentioned capacities implies a learning process [23,24]. A powerful method for such a learning process is the co-creation of knowledge and skills [25]. This means that the local and practical knowledge of the community—including local municipality workers—and the scientific knowledge of the researchers (and students) merge into new knowledge [26,27]. While intervention research has traditionally privileged formal academic theories above local wisdom, as Berwick [28] argues, those individuals involved in making changes in complex systems will often know more about mechanisms and contexts than third-party evaluators can learn without getting involved. Hence, co-producing interventions with stakeholders with intimate knowledge of the systems they attempt to alter represents an important means of ensuring congruence between theory and context [29,30].

The co-creation of knowledge can and should take place in all phases of a project: start-up, research, design and dissemination [12,31–34]. In each of these phases, the local community and the researchers contribute different types of knowledge. For instance, the community makes its social network knowledge available to the researchers, who use this for a network analysis. Co-creation ensures that the civil society organization (1) is actively involved in all phases of the project, (2) needs to look for knowledge that it can use and (3) learns from the knowledge that the researchers provide. Intervening scientists should contextualize scientific knowledge and concepts and adapt them to the local situation [33]. This implies that during the project the community is also involved in a learning process, which is the basis for empowerment: the capability to keep the project running after the student intervention has stopped.

When students and university staff intervene in a socio-ecological system, they become temporally part of that system. This shifts their role from working for to working with the local community [34]. Characteristic of such a learning network is that everybody brings and acquires knowledge; everybody learns from everybody [35].

## 2. Materials and Methods

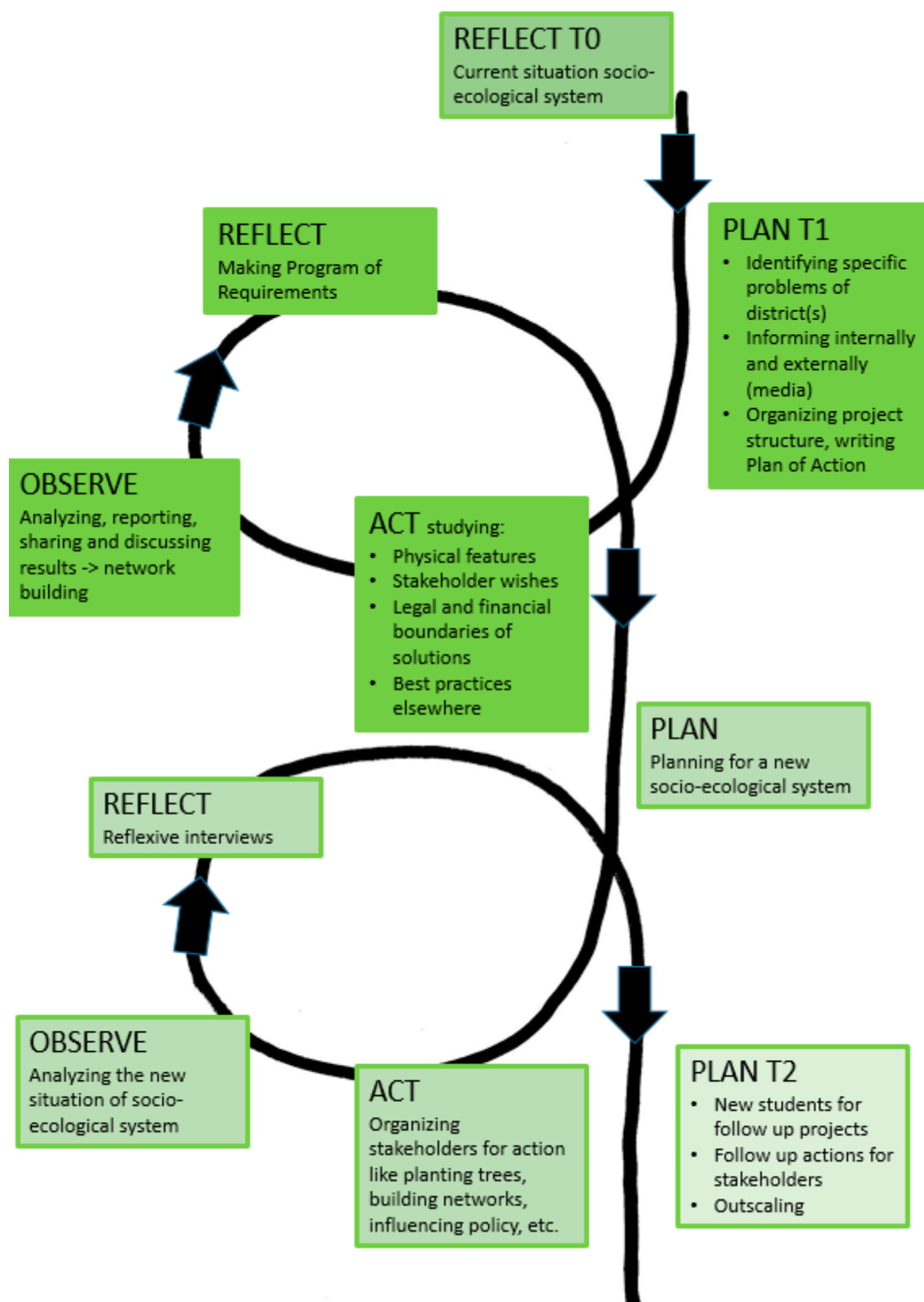
To reach our aim of analysing the impact of student interventions in urban greening processes, participatory action research was undertaken. This type of research fits very well in this situation because it aims to change specific situations by “seeking contextualized truth” [36]. Action research often takes place in (multiple) cycles [37,38], where planning, acting, observing and reflecting follow each other in logical order, with one round of the cycle stimulating the next. In action research,

doing research *with* others instead of doing research *on* others is pivotal [36]. That means that the steps in these cycles are jointly taken, each participant doing what he can do best, thus co-creating the process.

Two cycles of participatory action research were undertaken (Figure 3). In the first cycle students conducted interventions in two case study areas, one in the city of Haarlem [39] and five others in the city of Enschede [40–44]. The student projects lasted three months. However, before that, regular contacts between university staff and case contact persons warmed up the situation (first stages of Plan T0).

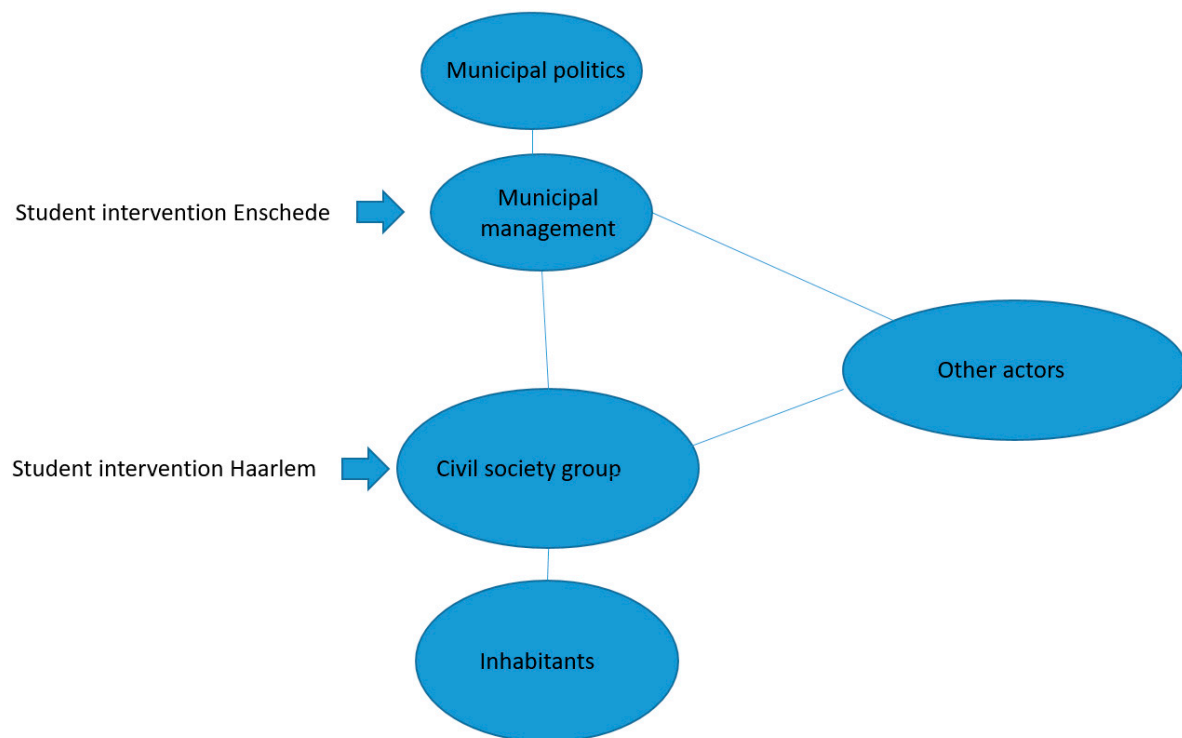
In the first round, during the Act phase, the students studied the physical features of the district and its surroundings (using a combination of site factors and ecological networks as a frame [45]), wishes of stakeholders, legal and financial boundaries of solutions and best practices elsewhere. The commissioners of the students supported this work by distributing a questionnaire, introducing the students to other stakeholders and making maps and data available. In the Observe phase, the students discussed the results with stakeholders, often supported by the commissioner, who would use his network to organize the meetings. In the Reflection phase, all researched elements were combined in a programme of requirements. This is a way to connect the outcomes of the Observe phase with the second Plan phase [46,47] and to get an agreement between stakeholders and students about the direction of the solutions in the second Plan phase. These solutions were again discussed by the stakeholders and used to broaden their social network. The Act and Observe phases in the second round were mainly done by the commissioners and other stakeholders, while the Reflection phase was done by the researchers. Using the socio-ecological system criteria (Appendix A, Table A1) in combination with network learning and empowerment theories as an interview guide, information was gathered from students, university staff, a civic society group (Haarlem) and the municipality (two levels in Enschede). Students and university staff obviously could only give information about the first cycle of the process. Questions were asked about the change in (the criteria of) the socio-ecological system, the contribution of the different research parties: commissioner, other stakeholders, university staff and students, the mutual learning process and empowerment.

Based on the reflexive interviews, plans were made to formulate new student projects to fill in the gaps in the current knowledge and network.



**Figure 3.** Action Research cycles applied to case studies (inspired by [37,38]). At time 0 (T0, see also Figure 2), the commissioner started the cycle by reflecting on the current situation. The process consisted of two cycles (T1 until T2). Student involvement was heavier in the first cycle and in the upcoming cycles (T2).

Choosing Haarlem and Enschede was partly due to a coincidence and the social contacts between university staff and people living or working in these cities, but the latter are exemplary of many middle-sized cities in the Netherlands. The level of the intervention in the governance system differed in Haarlem and Enschede (Figure 4). In Haarlem the intervention was on a lower level than in Enschede. The hypothesis was that this had consequences for empowerment and network building. In Haarlem the effect was expected to be larger, because the civil society group can more easily expand the amount of members and their network. Besides, more empowerment was expected, because one can imagine that members are more emotionally attached to their environment than managers.



**Figure 4.** Level of intervention in the governance system.

### 3. Results

#### 3.1. Enschede

##### 3.1.1. Social, Economic and Political Setting

The policy of the municipality of Enschede is to increase its biodiversity [48]. It is for example active in stimulating green roofs (Green Deal Green Roofs) and in making the city climate-proof using biodiversity measures. It also strives to maintain the green wedges that connect the city with the surrounding countryside [49]. The studied districts are part of these connections (Figure 5). However, Enschede is a relatively poor municipality, so no additional funding is available for ecological measures. Ecology should be combined with other needs such as climate-proof development and liveability.

##### 3.1.2. Resource System: The City District

The five researched districts differ substantially in layout. In the city centre, the amount of green area is very small (RS3). In the southern part of the city, many sporting facilities cluster together, making a large green area (perhaps) suitable for connecting the city with the outside. One of the large entrances of the city has been reorganized with a beautiful long row of oak trees, that has been attacked, however, by the oak processionary caterpillar. The ecological resource system is not yet resilient enough to solve the ecological and societal problems of the city.



### 3.1.3. Resource Units

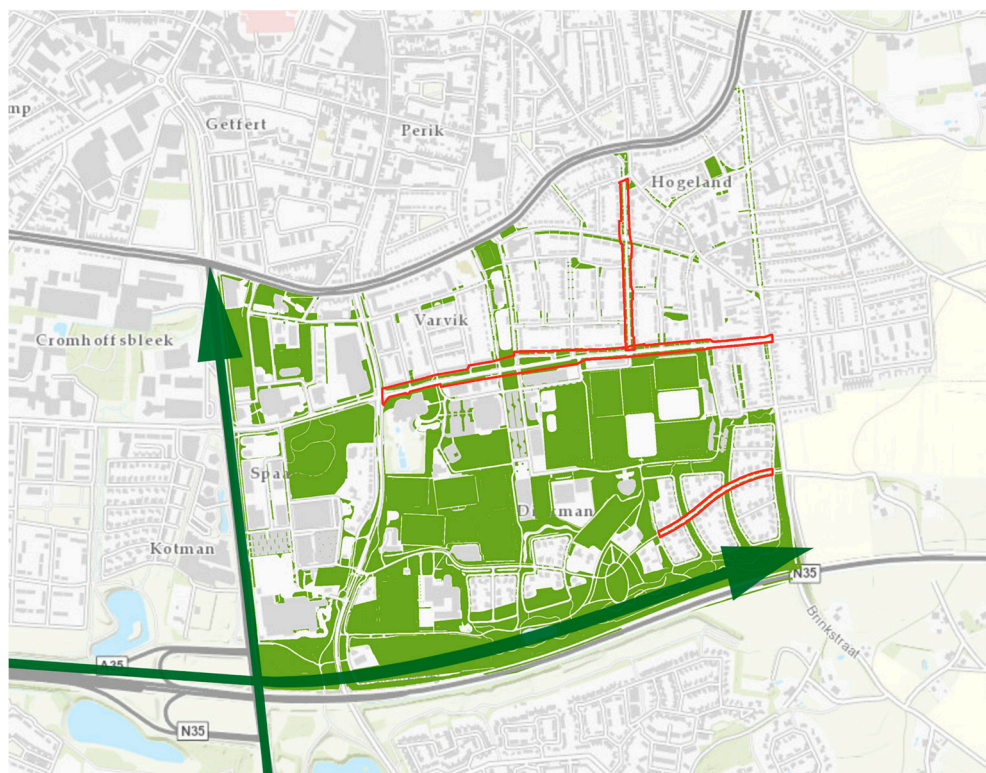
Resource units range from large-scale parks and sport facilities to smaller elements like lanes, green fields, pocket parks, flower strips and flower boxes. It is unclear how these elements interact (RU3) ecologically and socially. In other words, it is unclear how ecologically well connected the elements are and to what extent they provide ecosystem services. The students were able to offer a first glimpse on the potential of the resource units for providing ecosystem services (liveability, biodiversity, combat oak recessionary caterpillar) and connecting the ecological elements (as stepping stones or corridors).

### 3.1.4. Related Ecosystems

The starting point for the studies was to connect nature within the city and the surrounding countryside. The students suggested attracting species already existing in the city's surroundings by improving their living conditions in the city. They also designed stronger relations for these target species between ecosystems within and outside the city, thereby increasing the ecological connectivity (RU3, ECO3).

### 3.1.5. Governance System

The governance organization (GS1) in Enschede consists of district managers operating independently from the central ecological department of the city of Enschede. These district managers are in close contact with users (e.g., inhabitants) and other green managers (e.g., for playing fields, industrial areas, GS2).



**Figure 5.** Mapping of green infrastructure in Enschede Zuid (light green), the green corridors connecting the city with the surrounding countryside (dark green arrows) and the studied streets and lanes (red) that, if improved, can add quality to the ecological network and fulfil social needs [40].



### 3.1.6. Actors

District managers were important to introduce the students to the actors and to provide background information (e.g., ecological maps). The students' and district managers' joint learning (I2) was one of the major success factors in this project. The district managers are normally very practical workers, bound to a strict routine. Working together with students made them reflect on their routines, finding new ways of working. The higher the interaction between students and the district manager, the more enthusiastic the district manager became with regard to ecological solutions (A6).

Part of the student work was to make a network analysis (A2 socioeconomic attributes). Although most of the actors were already identified by the district managers, what they knew and wanted was relatively unknown. Providing this information was one of the success factors of the project.

### 3.1.7. Interactions

Students were important for connecting different stakeholders (I8). It was easier for them to talk with the stakeholders than for the municipality (I2,3,4). In some cases, the municipality had spoken to the stakeholders earlier, but these attempts had failed because the municipality was not trusted (I4), and biodiversity was characterized in advance as "sloppy and unkempt". The stakeholders were more open and less suspicious towards the students. In this way, the students gained an overview of the social context of the ecological issues. This was helpful in approaching the right stakeholders to test possible ecological improvements.

Students were asked to—and were able to—show the connections between the potential of the resource units, on the one hand, and demands of the different actors, on the other hand. Their spatial plans showed opportunities to connect the different wishes of actors in one ecological plan (I3). For instance: connecting the surroundings of the city's entrance with parks nearby in a more ecological way, in combination with a different management of the grass vegetation below the oak trees, makes it possible to control the oak processionary caterpillar. However, this was only possible taking into account the expectations of the surrounding inhabitants and entrepreneurs regarding the image of the area (not too sloppy). Or: adding green elements to the paved town centre introduces stepping stones for certain insects, apart from increasing the liveability of the area. Or: removing fences and adding flower strips to the sporting fields increases the ecological connectivity inside and outside the city for people and wildlife, in combination with an improvement of liveability. In other words: they invented integral solutions combining societal and political goals and (financial) resources.

### 3.1.8. Outcomes

What has been done with the ideas of the students? Some of the solutions proposed by the students were discussed in the municipality council. The work of the students, their being present and visible, in combination with existing policy, has moved biodiversity higher up the political agenda.

One solution proposed by the students is being implemented (Hengelosestraat, measures against the oak processionary caterpillar). Some will definitely be implemented (Enschede central, façade gardens) (O2). The lessons learned are being used in other neighbourhoods (Enschede South, sport park; outscaling, [17]). The most crucial outcome, however, was the empowerment of the district managers, who have gained insight into ecological solutions and social opportunities to combine societal needs and the increase of biodiversity.

## 3.2. Haarlem

### 3.2.1. Social, Economic and Political System

The municipality of Haarlem has formulated a policy to plant many trees in the city. It has also paid special attention to the greening of various paved districts, like the Indische Buurt [50]. However, really large changes in policy have not yet taken place, and the inhabitants feel much resistance in the governmental system. In most of the districts, neighbourhood groups are active, focusing on increasing

the districts' liveability. This is also the case in our study area, the Indische Buurt. This neighbourhood group contains several subgroups, including the “Green group”, which is active in promoting more natural elements in the district. This group was the commissioner of the students.

### 3.2.2. Resource System: The City District

The Indische Buurt is the most paved area of Haarlem [50], causing flooding during extreme rains [51] and urban heat. Three (projected) ecological connections run through the area: Jan Gijzenkade, Spaarnhovenstraat and the Zaanenstraat (Figure 6). Action is needed to develop these connections, because the Zaanenstraat and Spaarnhovenstraat, especially, are not really functioning as corridors; it is not even specified for which species the corridors should function.

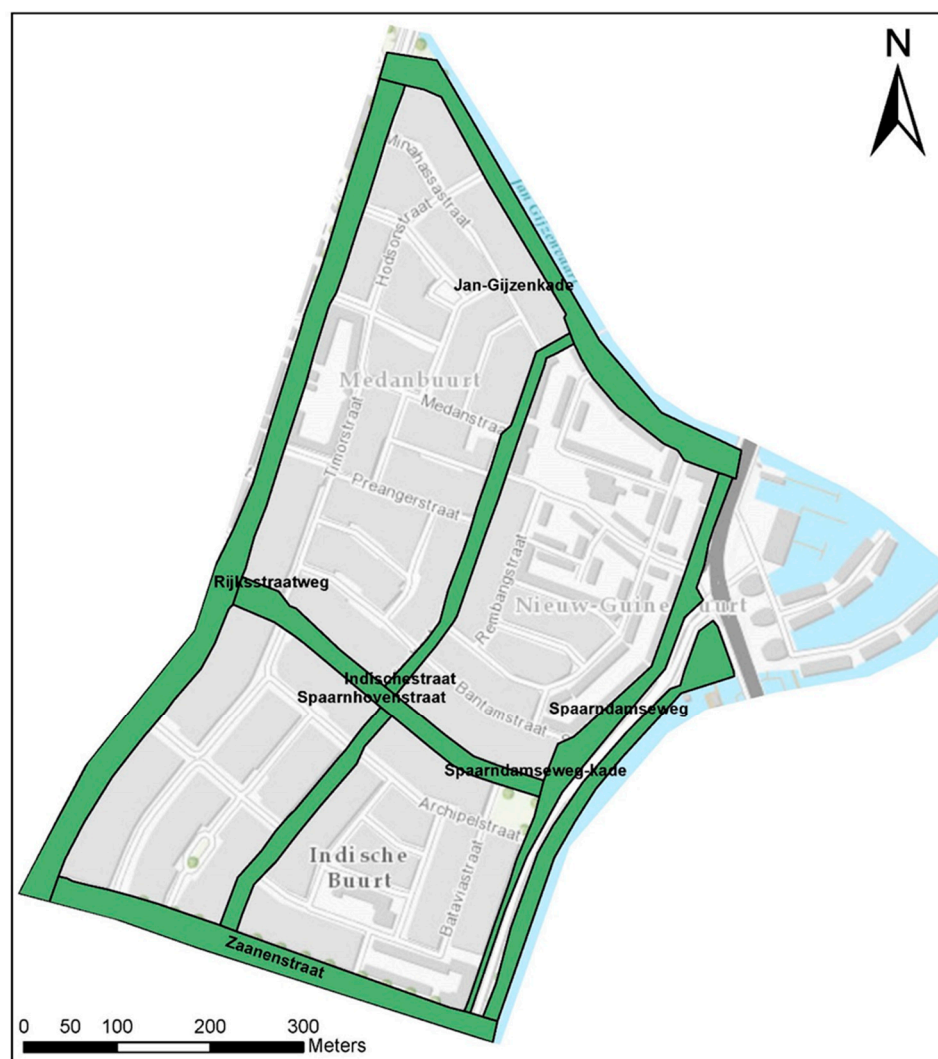


Figure 6. (Potential) ecological routes in the Indische Buurt, Haarlem [39].

### 3.2.3. Resource Units

The size, condition and age of green structure elements are very poor. Trees are often removed before they can reach maturity because of the “nuisance” they cause, like the shadow they cast, the falling leaves and the damages to the pavement.

### 3.2.4. Governance System

According to the Green group, the municipality is amorphous. Council, councillor, city officers, “green connectors”, management organization, all have different ambitions and different ways of working (GS1). This is making the cooperation with the civil society groups difficult, because they get different messages from different layers in the municipality system [7] (GS3). The housing association and healthcare organization are easier to approach, because these are smaller organizations with less management layers (GS2).

### 3.2.5. Actors

The presence of the students had a large impact on the work of the Green group. “Green” got a higher priority than it had before, just because students worked on it (A6). This meant that meetings should be organized for the inhabitants (the members of the neighbourhood organization) and for other stakeholders. During these meetings, the members of the neighbourhood organizations also started to understand the meaning of city ecology, the importance of coherence among ecological elements and vice versa. The already existing network of the neighbourhood group was very important for the start of the Green group and the student group. The neighbourhood group could introduce them to all sorts of other networks, related to politics, the media, healthcare organizations and other actors.

Another major player was the healthcare group situated in the district. They saw the changes made by the Green group and asked them to do the same for their property. This led to a complete change of the paved backyard of the healthcare building into a green area. The healthcare group saw the advantage of green spaces for health and saw that the Green group had the ability to guide the changes. Besides social actors, market actors are also hooking up in private-social partnerships [52]. A landscape architect, for instance, is introducing new technologies (A9) that can move the process further.

### 3.2.6. Interactions

The students provided knowledge about the inhabitants’ wishes related to green infrastructure by conducting a survey (A2, I10) and conveying ecological knowledge to the Green group. This knowledge was a powerful instrument in discussions with the municipality because the survey results indicated a wide support for more green areas and gave insight into the poor ecological situation.

Students and the Green group collaboratively organized meetings to discuss the results obtained by the students. These meetings and workshops helped the Green group, the inhabitants and other stakeholders to achieve self-organization (I7). It helped them to think about who and what was needed for the organization to develop. The Green group needed to divide work, to start a website and planting activities and to appoint people that would liaise with other groups, the municipality and the district group (A5). The Green Group also welcomed new members with critical knowledge (A1).

### 3.2.7. Outcomes

The proposed solution for the area was twofold: enhancing the ecological infrastructure for target species along the larger streets and enlarging the possibilities for “fun green” in the other areas. In the latter case, significant progress has been made. Many communal and individual green projects were established: about 200 façade gardens, tree driplines, flower boxes, flowerbeds, etc. (O2). Finding money for smaller or even larger projects like the greening of the garden of the healthcare organization became easier because of the fast first results in smaller projects. However, there was no progress in the ecological infrastructure, as in this case the support of the municipality was essential. This concurs with the idea of Buijs et al. [17] about mosaic governance: the aims of the government and society are diffuse and should overlap to become significant.

Another outcome of the intervention was the significant widening of the network (it has been upscaled, cf. [17]). Not only has the amount of individuals active in the Green group increased considerably, but the amount of groups attached to the Green group has also grown (municipality,

healthcare group, green delivery group Spaarnelanden, nature education group, housing association, salvation army, etc.). Consultations with similar groups in other districts, which would help them to learn from each other (outscaling [17]), has not yet taken place. The Green group saw the advantages of coordinating with other green groups in Haarlem, for instance to stand stronger in engaging with the municipality, or because green structures do not end at the border of the district. However, there was no time or energy to organize this. Here, the borders of voluntary work are visible. However, within the socio-ecological system, empowerment in economic (subsidies I5), psychological (knowledge, self-confidence), and social (networks) terms has grown, but not yet in political terms.

Based on the reflexive interviews, the need was felt to introduce new students to work on enhancing citizen science, in order to assess the improvements of the ecological infrastructure and to strengthen citizen involvement in greening the city. This could also lead to new alliances with ecological inventory groups, which is a positive side effect of assessment procedures [53].

## 4. Discussion

### 4.1. Factors Causing Change in the Cases' Socio-Ecological Systems

When students and university staff intervene in a socio-ecological system, they become temporally part of that system, learning and acting together with other actors. Their main contributions to the socio-ecological network were the increase in the amount of interactions, especially information sharing (I2), and the evaluations (I10), but also the networking activities (I8) and self-organizing activities (I7). They speeded up the interaction between the stakeholders and between stakeholders and the ecological system. They have raised the amount of knowledge available in the network (I2, I8, I10) and enlarged the network itself (A1). Especially in the Haarlem case, the network grew substantially, while in Enschede the main result was the strengthening of the existing network. The students paved the way for the district managers by mapping the wishes and concerns of the stakeholders and giving them a voice in the process of producing solutions (I3).

Students have started network learning. In Enschede, the district managers worked in close cooperation with the students. Afterwards, they were more able to combine Enschede's ecological policy with their daily managerial work, had more knowledge about how to combine societal needs with ecological goals (e.g., liveability with ecology) and had a better understanding of the values and wishes of other social actors. In Haarlem an increase of the knowledge of the civil society group took place: together, the members of this group were more able to put their wishes into action. The students and university staff brought contextualized knowledge about ecology in the city [54]. The combination of ecology and landscape ecology (site factors and ecological networks) was innovative. Mapping the wishes of inhabitants regarding green areas in the city and searching for overlapping values (ecology, liveability, climate) was also very helpful in the discussions with other actors.

Students have triggered change by interacting with other actors, including researchers, the municipality and other stakeholders. All have contributed their share in a learning network [35]. However, on top of that, one might say that the students brought a certain urgency that speeded up the process, especially because everybody knew the students would be present for a limited amount of time. Besides, the students brought qualities to the process that other actors did not have, (or at least not in the same amount): time, thinking out of the box and a certain innocence, as they (unconsciously) used their outsider position to ask questions that more involved people cannot ask. Students can bring excitement, action and energy. Their mere presence can make a difference and start a process of change. However, the university staff need to keep the focus on long-term effects and empowerment, because students do not have a sufficient awareness of these issues. The university staff know more about the process management and research methodologies. They can also facilitate the start-up phase of co-creation, prepare the students' arrival and make their project more effective in creating change. In a learning network all parties play their own role.

In Haarlem the intervention was primarily aimed at the lower levels of the governance system, while in Enschede it was aimed at a higher level. The hypothesis was that differences in the level of intervention in the governance system would have a different effect, but in both cases student intervention brought empowerment to the local stakeholders. Even a year after the initial intervention, the effects were still visible and gaining strength. In Haarlem the community group was psychologically (learning), socially (networks) and economically (finding funding) empowered, but not yet politically (elements of the definition of Fraser, [20]). In Enschede the municipality workers gained political (support of councillor), social (internal and external network), psychological (learning) and economic (finding new funding with the help of the students plans) strength. The different cases showed that the closer the cooperation between students and local stakeholders, the higher the empowerment, even when the quality of the end-product was not very good. The general conclusion is that the quality of the student process is more important than the quality of the student product.

In Haarlem the change in the social system was limited to the change in (thinking of) the organizations of the neighbourhood association and the healthcare organization. No change took place in the organization of the municipality. Because of this, changes in the ecological system were also limited to smaller plots and the garden of the healthcare organization: with great success, a large amount of smaller and medium-sized projects were implemented. The ecological infrastructure, which is primarily the responsibility of the municipality, has not yet been implemented. In Enschede changes took place in some stakeholder organizations but also in some parts of the municipality. Because of these rather large changes achieved in the social system, major changes in the ecological system were and will be reached as well. One of the main success factors was the strengthening of the network between the central municipality policy and the area managers, on the one hand, and between the district managers and local stakeholders, on the other hand. Because of the lower level of intervention in Haarlem (on the civil society level), this fruitful linking of the network within the municipality was not happening yet.

#### *4.2. Reflection on the Learning Process and Theory*

The aim of the study was to determine the contribution of student interventions in urban greening processes. However, two other aspects were considered important enough to be discussed in this paper, namely the effect of the intervention on the students' learning process and possible additions to the used theories.

The students did not learn only from teachers and the literature, but also from others in learning networks. They learned to combine scientific knowledge and laymen's knowledge. "In particular the project enabled students to develop a range of skills beyond those found in typical academic work and in particular those which are hard to simulate in the academic setting: collaboration, peer learning, negotiating, communicating, and professionalism" [34]. Students learned how to bring about change, not only about describing the state of the art, not only about describing the future in a plan, but also about guiding change in a process. In real life, change is more important than a report. However, the students were relatively unaware of their influence on the socio-ecological system and the empowerment of the stakeholders. This is due to the fact that their attachment to the case only existed for a limited amount of time. After three months, their focus shifted to another school period, so they did not see the changes that took place afterwards. Besides, during their work on the case, their focus was mainly on the product, not on the process. The latter can easily be changed by introducing performance indicators for the students. The former is more difficult. The options are: asking the collaborating local organization to keep the students informed after they have left the scene or using these successful examples in education for students of the following years.

There is not much emphasis on change in the socio-ecological system framework describing sustainable or non-sustainable systems, although such change is often necessary to work on sustainability. This can be an addition to the challenges that Partelow [55] described for the socio-ecological system framework. A combination of learning and empowerment can be of help here.



In the researched cases, empowerment and network learning have proved to be mostly part of the interaction subsystem (I) of the social ecological network.

Theoretically, empowerment is often projected on, and reserved for, civil society groups. However, when viewing the situation as a learning network, parts of the municipality and other actors should also be taken into account. In Enschede the empowerment of the lower levels of the municipality (district managers) was of crucial importance. Empowerment should therefore be seen as a network activity. In addition to this, long-term green management (place keeping, [21]) is often neither undertaken by local communities nor by the municipality alone. It is often undertaken in a network, sometimes with more emphasis on green management by local communities (in Haarlem, e.g., tree driplines), and sometimes with more emphasis on green management by the municipality (e.g., ecological infrastructure), but both are needed. Longitudinal research is needed to further explore the mutual development of municipalities, civil society groups and other stakeholders to reveal critical success factors for place keeping.

As stated in the theory section, the co-creation of knowledge can take place at all stages of a project. This is true from the perspective of the intervening organization, for which the intervention is a project. The actor network (including civil society groups, municipalities, etc.) receiving the intervention is, however, in a process of change, where actors come and go (e.g., students with projects), or become temporally more or less important (e.g., municipalities, healthcare organizations, sports organizations). Empowerment theories should therefore also include the ability to find actors that are necessary at that specific moment in the process to learn and act together.

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## Appendix A

**Table A1.** Student contribution to changing the socio-ecological system.

Criteria for Mapping a Socio-Ecological System [13].		Contribution of Students to Changing the Socio-Ecological System
Social, economic and political settings (mostly city level)	S1 Economic development	S3 Indirect to new political coalitions (see outcomes) S6 Contribution to PR (radio, newspaper)
	S2 Demographic trends	
	S3 Political stability	
	S4 Other governance systems	
	S5 Markets	
	S6 Media organizations	
	S7 Technology	
Resource system (the city district)	RS1 Sector (e.g. water, forests, pasture)	RS2 Mapping ecological connectivity with other systems RS3 Mapping of green infrastructure RS4 Mapping of buildings and paved area RS8: Rudimentary mapping of water storage capacity
	RS2 Clarity of the system boundaries	
	RS3 Size of the resource system	
	RS4 Human-constructed facilities	
	RS5 Productivity of the system	
	RS6 Equilibrium properties	
	RS7 Predictability of system dynamics	
	RS8 Storage characteristics	
	RS9 Location	



Table A1. Cont.

Criteria for Mapping a Socio-Ecological System [13].		Contribution of Students to Changing the Socio-Ecological System
Resource unit (ecological elements)	RU1 Resource unit mobility RU2 Growth or replacement rate RU3 interaction among resource units RU4 Economic value RU5 Number of units RU6 Distinctive characteristics RU7 Spatial and temporal distribution	RU3 Mapping ecological connectivity within the system RU6 Mapping different types of ecological elements RU7 Mapping spatial distribution of the different ecological elements
Related ecosystems	ECO1 Climate patterns ECO2 Pollution patterns ECO3 Flows into and out of SES	ECO1 Detecting heat islands ECO3 Mapping connectivity outside resource system
Interaction (within and outside resource system)	I1 Harvesting I2 Information sharing I3 Deliberation processes I4 Conflicts I5 Investment activities I6 Lobbying activities I7 Self-organizing activities I8 Networking activities I9 Monitoring activities I10 Evaluative activities	I2 Organizing meetings, workshops, presentations: matching local knowledge with scientific knowledge I3 Supporting local actors by organizing workshops with stakeholders. Showing the value of connecting social values (e.g., liveability) and ecological values (integrated solutions) I4 Intermediary in potential conflict situations between stakeholders I6 Supporting lobbying by providing knowledge about the social and ecological system I7 Entrance of students triggers self-organizing activities I8 Organizing meetings, workshops, presentations. Connecting different stakeholders I9 Monitoring the ecosystem and social wishes/demands I10 First steps in supporting citizen science (counting birds, plants, insects)
Governance systems	GS1 Government organizations GS2 Nongovernment organizations GS3 Network structure GS4 Property-rights systems GS5 Operational-choice rules GS6 Collective-choice rules GS7 Constitutional-choice rules GS8 Monitoring and sanctioning rules	GS3 Strengthening the network

Table A1. Cont.

Criteria for Mapping a Socio-Ecological System [13].		Contribution of Students to Changing the Socio-Ecological System
Actors	A1 number of relevant actors A2 Socioeconomic attributes A3 History and past experiences A4 Location A5 Leadership/entrepreneurship A6 Norms (trust – reciprocity)/social capital A7 Knowledge of SES/mental models A8 Importance of resource (dependence) A9 Technologies available	A1 Student activities lead to increased amount of connected actors. A2 Students invest time and add scientific knowledge A5 The entrance of students provokes leadership because the project needs to be organized. It also encourages the local actors to become a change agent by adding knowledge, network. A6 Students are trusted by almost everybody, they open doors for other actors. Increasing enthusiasm for green solutions by other stakeholders A7 Knowledge about the effect of human beings on the ecological system A8 Stressing the importance of the ecological infrastructure for the actors involved A9 Providing knowledge about maintenance
Outcomes	O1 Social performance measures O2 Ecological performance measures O3 Externalities to other SESs	O1 Contribution to empowerment (in the resource system and in political setting) by adding knowledge, network, activities (buzz) O2 Contributions to planning ecological infrastructure and integrating social (e.g., liveability) and ecological needs. O3 Contribution to exporting knowledge to other districts

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