Raffles Institution
Year 2 Research Education
Final report

How to harness green roof technology in schools to encourage Singaporean students, through CCAs, to play an active role in reducing carbon footprints and controlling the negative effects of greenhouse gases?

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Abstract

In Singapore, many students do not see the need to protect the environment. Thus, this study seeks to investigate the feasibility of educating Singapore youth about the environment and encouraging them to play an active role in environmental protection through the use of green roofs in schools. Surveys were conducted, and most respondents were secondary school students. An interviews was also conducted with two interviewee from secondary school to gain insight into the matter. After further analysis, it was observed that most did not really know about green roofs, but had a positive perception of green roofs. They also had moderate environmental awareness. Thus, active participation in environmental protection through the use of green roofs should be possible with more education about green roofs and the severity of climate change, and how to play an active role in minimising their carbon footprint.

Contents

1 Introduction

1.1 On green roofs

1.1.1 Definition

Green roofs involve growing plants on roofs, which can be sorted into muscinal roofs, herbaceous roofs and arbustive roofs (Madre et al., 2013).

1.2 Benefits

They can reduce energy demand on space conditioning, help in purifying air, and if widely adopted, could reduce the urban heat island effect, among other benefits (Liu, 2002). These benefits will be further looked into in Section 2.1.

1.3 Purpose and significance of research question

1.3.1 Purpose

To find ways to, through green rooftop technology, increase Singapore students' awareness of climate change and how they can play a part in reducing it. See below for more information as to how this topic is relevant to today's dynamic and modern society.

1.3.2 Significance

Understanding climate change is of significant importance in today's society, as it poses a large problem to the environment. We think that harnessing green roofs may be able to encourage students to take action against this. The effects of climate change and how green roofs can help are further studied in Section 2.2.

1.4 Target Audience

We chose primary and secondary school CCAs as our target audience as they are old enough and mature enough to understand the implications of global warming and climate change, and global warming. They will also be the leaders of tomorrow, so it is even more important for them to understand this.

1.5 Adoption

If adopted in schools by having students to take care of and keep up the green roofs, the students would then build this habit of caring for and maintaining a green roof, something they would hopefully continue to do upon reaching adulthood in the future when they would be able to realise human impact on the environment. This is even more important should they become national leaders, who have the power to influence the lives of other people. Having this influence from young, they would then turn to such technologies which can affect climate change for the better.

2 Literature review

2.1 Further study of the benefits of green roofs

2.1.1 Economic

Research on green roof technologies has so far proven them beneficial, with Liu, 2002 mentioning that they can reduce energy demand on space conditioning and decrease temperature fluctuations. This is agreed on by Mithraratne, n.d. who states that increased roof insulation could reduce space conditioning required in the building. Other sources also mention the decreased carbon emissions due to lower energy consumption from improved thermal performance (Wilkinson et al., 2014) which reduces cost of energy as there will be up to a 75 percent decrease in energy usage for cooling the building, with daily averages dropping from 7.5kWh to 1.5kWh (Liu, 2002). Liu, 2002 also mentions that daily temperature fluctuations on roofing membranes are significantly reduced, which can increase the lifespan of the roof.

2.1.2 Environmental

Liu, 2002 states that if green roof technologies are widely adopted, they could reduce the urban heat island effect (a situation where an urban area has higher temperatures than surrounding rural areas) by having the plants on the green roofs absorb some of the heat. Hui, 2010 also suggests that it "mitigates the urban heat island effect". It is also said that green roofs can increase the aesthetics of urban landscape, reduce glare for surrounding buildings, showing its importance and relevance in today's highly urbanised society. Additionally, Hui, 2010 found that green roofs can mitigate air quality issues, which are important for the wellbeing of all. Therefore, we find that there is a need to educate students, especially those in secondary institutions (as they are mature enough to understand the gravity of global warming and climate change and the need to take immediate action, and are more likely to have time to undertake this project than those in tertiary institutions) about green roofs. Vegetation on green roofs help purify the air and convert carbon dioxide into oxygen, which reduces the amount of greenhous gases in the air. (Liu, 2002) mentions this, and Wilkinson et al., 2014 goes a step further, even suggesting that green roofs help achieve zero carbon footprints. The plants also take in rainwater, reducing the water in the sewage system which needs to be purified and discharged to the sea, helping

to stabilize the groundwater level and reducing the possibility of the sewer clogging and malfunctioning.

2.2 Climate change and how green roofs can prevent it

According to NASA, n.d., at the rate of climate change we are at, the sea levels worldwide would increase by 1–4 feet. This leads to the question of whether Singapore would truly be safe in the future. This thus draws the necessary attention and action of the Singapore Government and the citizens. Actions required includes educating the youth of the society of the consequences of climate change and the possible course of action. However, students in Singapore have "major gaps in their understanding [of climate change]"(Chang & Pascua, 2016), and thus will not see the need to protect the environment and prevent it. Therefore, it is necessary for us to research methods that can be used to raise awareness of climate change in Singaporean students. At the same time, we believe that green roofs can be an effective measure in fulfilling its purpose in combating climate change and in motivating the Singaporean youth to play an active role in it. Green roofs are a potential way to not only encourage the next generation of Singaporeans to take climate action, when the country is in their hands. Proper education of the youth would, hopefully, eventually lead to a rise in green technology and build a greener, healthier world for everyone to live in, one that is possibly freed of the grasps and struggles of climate change. Even in Singapore, green roofs have been utilised on buildings such as the Nanyang Technological University's School of Art, Design and Media. According to Berardi et al., 2014, green roofs not only play a part in helping to slow climate change, they also help create a better environment for residents.

3 Methodology

3.1 Purpose

We believe that green roofs are severely underused in Singapore despite the advantages, and think that schools are a great place to have them implemented. The surveys and interview we conducted were in order to find out Singaporean students' awareness and perception of green roofs, as well as the viability of, and their willingness to assist in green roof projects in schools.

3.2 Interview

An interview was conducted, on 28 June at 3pm. As the interviewee was unable to use Microsoft Teams due to a lack of access, we used other means to conduct the interview, such as Zoom or Discord video calls. The interviewee was a boy studying in West Spring secondary. During the interview, the interviewee was asked questions regarding the features, advantages, disadvantages and possible hindrances in their implementation. He was also asked about how he felt about implementing them on school roofs, and how he thought other students might feel about it.

3.3 Surveys

The survey respondents came from two different age groups: primary and secondary school students. In total, we received survey responses from 21 students, one of which was not a serious response (evident from the options selected, which were all falling in the "Strongly disagree", "False", or similar categories, even disagreeing to the PDPA clause). Hence, we chose to omit the data gathered from that respondent and focus on the other 20 respondents. However, 19 of the remaining 20 respondents indicated that they were of 13–17 years of age, and hence the demographics of our survey were quite limited and the data collected may (unfortunately) not be representative of the entire student population in Singapore. The questions to gauge their understanding were based on two research papers by Hui, 2010 and Liu, 2002.

4 Results and analysis

4.1 Summary and results

4.1.1 Surveys

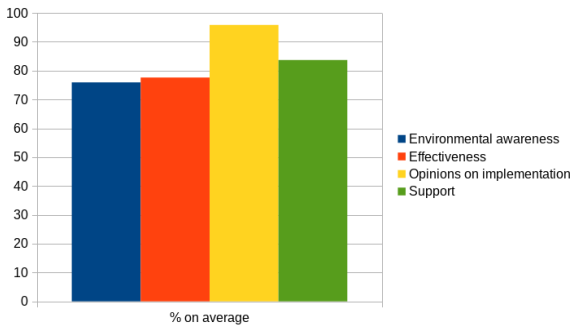

Figure 1: What respondents think of green roofs on average

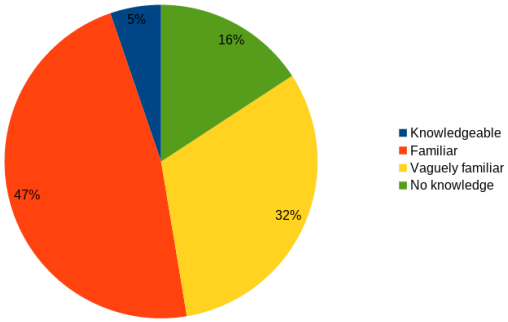

Figure 2: Knowledge levels of respondents

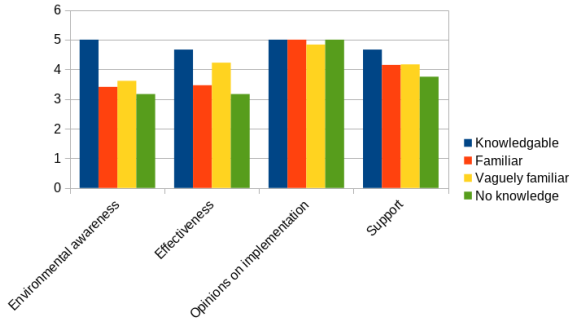

Figure 3: Subgroup analysis of Fig. 1: knowledge of respondents against what they think of green roofs

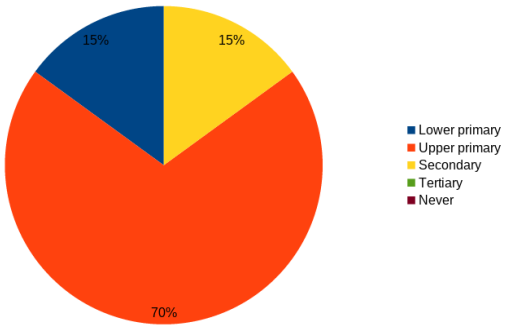

Figure 4: Respondents' opinions on when students should start getting involved in maintaining green roofs

4.1.2 Understanding and support of green roofs

The results also show that not many students have a good understanding of how green roofs work (as shown in Fig. 2), but are able to identify its benefits towards climate change, and would actively participate in reducing carbon footprint if green roofs were to be implemented in schools. This shows that people do not need to have a good understanding of green roofs, but only a general understanding that it benefits the environment and by helping maintain the conditions of green roofs would reduce carbon footprint. Unsurprisingly, the single respondent who indicated that he was "knowledgable" about green roofs was the most optimistic, fully agreeing to most of the statements. Furthermore, as is shown in Fig. 3, respondents with more knowledge of green roofs were, on average, more environmentally aware and showed more support, and thought they were more effective in general.

4.1.3 When students should start their involvement in maintaining green roofs

In general, we found that the majority of Singaporean students are supportive of the concept of green roofs, from Fig. 1.

4.1.4 Interview

The interviewee, who was quite knowledgeable regarding green roofs, responded by saying that green roofs served several purposes: collecting water and acting as insulators, among others. However, they also cost a lot to build, and require a lot of maintenance. Despite those disadvantages, he thought that they should be implemented on school roofs as they could reduce the amount of electricity spent on electricity as they act as an insulator, thus reducing costs.

4.2 Analysis

These results showed that in general, teenagers in Singapore were supportive of implementing green roofs. When asked about the practical usage of green roofs, 95% of respondents agreed on all aspects meaning that they believed green roof systems being implemented would be a good idea. The one respondent that did not agree on every aspect noted that building green roofs was a waste of effort, but agreed on all other parts. As is evident from Table 1, most respondents were rather willing to participate in the maintenance of green roofs, with only two respondents indicating their unwillingness to participate in the maintenance of green roofs.

In Section 1.4, we mentioned that our target audience would be primary or secondary school CCAs, as they would be more mature in thought and not as stressed as their seniors. However, as is shown in Fig. 4, survey results seem to suggest that students be introduced to maintaining green roofs at the upper primary level instead. After some thought, we decided that this would indeed be more appropriate, as environmental awareness should be instilled in youth from a young age.

Table 1: Number of respondents willing to do each maintenance duty

Pest control	Pruning vegetation	Adding compost	Monitoring plant growth	None of the above
12	12	11	12	2

The interviewee mentioned that green roofs would provide a better environment for students to learn in. This is presumably because green roofs act as insulators and can thus help keep air in the classroom cool naturally. He also mentioned that he did not know any schools that implemented green roofs. This shows that green roofs have not yet been adopted in Singapore schools. This is supported by "I highly doubt that it would actually be implemented as my school likes spend more of their budget on certain CCAs, but not on green roofs", implying that schools in Singapore do not yet realise the benefit of having green roofs.

5 Discussion and implications of findings

5.1 General perception of green roofs

Wilkinson et al., 2014 found that 55 percent of respondents to a survey conducted "strongly agreed" that greenery was important and its benefits outweighed its additional costs, showing public support of this idea suggesting that our idea may be quite welcome. This is supported by Mithraratne, n.d., who said that with therapeutic value of greenery in reducing stress already established, green roofs are used commonly in Singapore to soften the harsh urban environment and to improve the quality of life. Modern green roofs are now mainly based on cost, energy, water savings and carbon reduction (Mithraratne, n.d.). 71.8 percent of respondents in a survey conducted by Wilkinson et al., 2014 stated that greenery would make a place more attractive to live in meaning that greenery could have a positive impact on people's lives, especially for students who spend time in school. However, Castleton et al., 2010 also found that 33.8 percent of respondents to their survey had less than a general understanding of the concept of green roofs— with the oldest(76+) and youngest(12–17) age groups showing the least understanding, further stressing the need to educate students about green roofs, although this may be inaccurate due to the small sample size. However, Chang and Pascua, 2016, also found that students in Singapore do not fully understand climate change.

5.2 Possible implementations

We propose that students be grouped according to three different CCA groups: sports, performing arts and uniformed groups, with each group doing its own part. The students in sports CCAs and uniformed groups will carry out the physically more demanding tasks (e.g.doing the actual planting itself and taking part in maintenance with the assistance of professionals, etc.) since they are more used to carrying out such physical tasks than the students in performing arts CCAs. The students in performing arts CCAs can manage the logistics(planning projects, budgets, etc.) seeing that they are likely to be less physically inclined while everyone still keeping to the recommended guidelines by Hui, 2010.

We also think that more education to students about green roofs is necessary in order for them to fully understand their benefits. As shown in Section 4.1.3, students were generally more supportive of green roofs if that had more knowledge of them. However, Fig. 2 clearly shows that most students are lacking in knowledge of green roofs. Therefore we view further education on green roofs essential to achieving greater support for green roofs amongst students, thus making it more likely for them to be willing to participate actively.

6 Limitations

As we only had a limited amount of time, we may have collected insufficient data to fully justify our conclusion, hence the conclusion may not be entirely reliable; we only had 21 responses to the survey, one of which was illegitimate.

7 Conclusion

Current research has shown that green roofs can be beneficial by maintaining a stable temperature, reducing space conditioning, amongst other benefits. However, there is still a knowledge gap where Singaporean students' perceptions of green roofs and its viability in schools are not addressed which is why our research is relevant and necessary.

Our research suggests that students should be further educated on the severity of climate change, the pressing need to protect the environment, and of course, the benefit of green roofs. Upper primary students and perhaps secondary students should also play an active role in maintaining green roofs, which should be implemented in schools, so as to instil a sense of responsibility for protecting the

environment, and have them develop a habit of caring for it and playing an active role in preventing climate change.

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Appendices

A Survey questions

We are a group of Year 2 Students from Raffles Institution, and we would like to conduct this survey in order to gain important insights into the public perception of green roof technologies. Our project is centred around how the Singaporean public views green roofing and the viability of their implementation in schools. In this survey, we are talking about green roofs of the intensive type, where a variety of plants will be grown on a rooftop, instead of just grass.

All information collected will be kept strictly confidential and anonymous, with consent given, and will be for the sole purpose of conducting our research. The information will not be shared to any third party and we will not retain the information for longer than we need it in order to finish our research. Participation in our survey is consensual and voluntary, and I agree that the information shared here can be collected, used and disclosed to the relevant parties for the aforementioned research. Your consent for the above may be withdrawn at any point during the survey.

We would greatly appreciate it if you took a few minutes to complete this survey. Thank you for your time and effort.

Q1. What is your age?
- ☐ 12 years old and below
- ☐ 13-16 years old
- ☐ 17-18 years old
- ☐ 19-21 years old
- ☐ Above 21 years old

Q2. What category of Co-Curricular Activity(CCA) do you take part in? (Tick all that apply)
- ☐ Sports
- ☐ Performing arts
- ☐ Uniformed groups
- ☐ Clubs, societies and associations
- ☐ Others
- ☐ No CCA/Not applicable

Q3. On a scale of 1 (strongly disagree) to 5 (strongly agree), please indicate how strongly you agree with the following statements:

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The environment is in an undesirable and adverse situation.	☐	☐	☐	☐	☐
There are technologies available that can improve the state of the environment.	☐	☐	☐	☐	☐
Our environment can be improved through the use of green roofs.	☐	☐	☐	☐	☐

Q4. How familiar are you with the concept of green roof technologies?
- ☐ Never heard of them before this survey.
- ☐ I vaguely know what they are.
- ☐ I know some details on what they are and how they function.
- ☐ I can describe in some detail what green roofs are, their uses, and their advantages and disadvantages.
- ☐ I have experience and knowledge in the field of green roofing, whether as part of my occupation or as research done.

Q5. On a scale of 1 (strongly disagree) to 5 (strongly agree), please indicate how strongly you agree with the following statements:

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Green roof technology can reduce the effect of greenhouse gases on the environment.	☐	☐	☐	☐	☐
Green roof technology can reduce the cost of running a building.	☐	☐	☐	☐	☐
Green roof technology, if widely implemented, could help lower temperatures in an area of effect.	☐	☐	☐	☐	☐
Green roof technology can help improve air quality.	☐	☐	☐	☐	☐
Green roofs are aesthetically pleasing and can improve the visual appearance of a cityscape.	☐	☐	☐	☐	☐

Q6. Please tick under the correct column to specify your opinion on the practical use of green roof systems.

Question	True	False
Do you think green roofs can help improve the environment in Singapore?	☐	☐
Do you think it is a waste of materials to try and build green roofs on buildings?	☐	☐
Do you think it is a waste of effort to try and build green roofs on buildings?	☐	☐
Would you support the government's hypothetical decision to build green roofs on all buildings?	☐	☐

Q7. On a scale of 1 (strongly disagree) to 5 (strongly agree), please indicate how strongly you agree with the following statements:

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
More green roofs should be implemented in Singapore.	☐	☐	☐	☐	☐
Green roofs should become standard in Singaporean buildings.	☐	☐	☐	☐	☐

Q8. Please indicate whether you believe that the following statement is correct: I believe that my peers will be able to effectively care for and maintain a green roof system in a sensible manner.
☐ True
☐ False

Q9. When in a student's schooling life do you think green roofs start to be used in schools with student involvement in maintaining it?
☐ At the lower primary level (Age 7 and above)
☐ At the upper primary level (Age 10 and above)
☐ At the secondary level (Age 13 and above)
☐ At the tertiary level (Age 17 and above)
☐ Green roof systems in schools should NOT involve students.
☐ Green roof systems should NOT be implemented in schools.

Q10. Which of the following tasks would you be willing to perform? (Tick all which apply)
☐ Pest control(inc. Weeding plants, adding pesticide to soil etc.)
☐ Pruning vegetation
☐ Adding compost
☐ Monitoring and keeping track of the types of plants to ensure the absence of unwanted growths
☐ None of the above

PDPA clause: The responses given in this survey are, to the best of my understanding, wholly accurate and truthful, and I consent to allow the information shared in this survey to be used by the researchers for their research. My participation is voluntary. We sincerely thank you for your time taken to complete this survey. This data is to be collected for the sole purpose of furthering our project on the topic of green roofs, and the possibility of their utilisation in schools. Strict confidentiality and anonymity of the information shared is assured. The personal data will not be shared to any third party or transferred overseas, and will not be retained for longer than is necessary to pursue our research. Your consent to participate in this survey may be withdrawn at any time. If you desire so, we could send our final report to you. For any further queries, please contact any of us at 24YCHON155F@student.ri.edu.sg, 24YLEEJ623C@student.ri.edu.sg, 24YTENG305C@student.ri.edu.sg, or 24YYEOJ426G@student.ri.edu.sg . Thank you.

□ I agree

□ I disagree

B Interview transcript

Interviewer: What do you think are some advantages of green roofs?

Interviewee: They serve several purposes– collecting rainwater, acting as insulators... They help reduce the risk of endangered species going extinct and provide better living conditions.

Interviewer: Ah, I see... then what are some disadvantages then?

Interviewee: They cost a lot to build them and require a lot of maintenance.

Interviewer: In that case... How do you think these problems could be solved?

Interviewee: Uhh... I'm not really sure...

Interviewer: It's all right. So, do you think it is a good idea to implement green roofs on school buildings?

Interviewee: Yes, I do, I think it is a good idea to implement green roofs on school buildings as it provides a better environment for teachers to teach in, and a better environment for students to learn in. They also act as insulators, so they are also more eco-friendly than normal roofs, reducing the cost of of electricity spent on air conditioners and cooling systems.

Interviewer: Do you know any schools which implement green roofs?

Interviewee: No, I don't think so.

Interviewer: Alright then. Would you support their implementation in schools then?

Interviewee: I would advocate it, but I highly doubt that it would actually be implemented as my school spends more of their budget on certain CCAs, but not on green roofs. Otherwise it is a very good idea.

Interviewer: Would you be willing to maintain a green roof should one be implemented in your school?

Interviewee: Yes, I would, as it benefits everyone and I have some spare time.

Interviewer: What about other students?

Interviewee: They may be willing.

Interviewer: If not, how do you think they could be convinced or persuaded to help out?

Interviewee: Perhaps a social media campaign could be launched to alert them about then benefits of green roofs and ask them to help.

Interviewer: And what incentives do you think could help attract them?

Interviewee: Perhaps giving out free green tea to do maintenance work as students like green tea.

Interviewer: Alright, thank you for your time! Do you have anything else to add?

Interviewee: Nope.

Interviewer: Alright, thanks!

C Research project timeline

Table 2: Our Timeline

Time	Goal
T1W5–T1W9	Group Project Proposal
T1W9–T2W3	Literature review
T2W3–T2W7	Finish finalised survey
T2W7–T3W1	Administer survey
T3W1–T3W4	Data analysis
T3W3–T3W9	Prepare for oral assessment
T3W4–T3W10	Finalise written report