

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 interview was also conducted with two interviewees 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.

### **Acknowledgements**

We would like to specially thank our teacher-mentor, Dr. Tan Guoxian, for his invaluable guidance and support throughout the process of our research. We would also like to thank all our respondents who are willing to spend time and effort into our survey and the interviewee who was willing to arrange a suitable time for us to meet with him and spent time and effort going through questions with us. Lastly, we would like to thank everyone else who has helped out throughout our research project; our research project would not be possible without you.

# Contents

|   |           |
|---|-----------|
| <b>Abstract</b>   | <b>I</b>  |
| <b>Acknowledgements</b>   | <b>II</b> |
| <b>1 Introduction</b>   | <b>1</b>  |
| 1.1 On green roofs  | 1         |
| 1.1.1 Definition  | 1         |
| 1.2 Benefits  | 1         |
| 1.3 Purpose and significance of research question                             | 1         |
| 1.3.1 Purpose   | 1         |
| 1.3.2 Significance  | 1         |
| 1.4 Hypothesis  | 1         |
| 1.5 Target Audience   | 1         |
| 1.6 Adoption  | 1         |
| <b>2 Literature review</b>  | <b>1</b>  |
| 2.1 Further study of the benefits of green roofs                              | 1         |
| 2.1.1 Economic  | 1         |
| 2.1.2 Environmental   | 1         |
| 2.2 Climate change and how green roofs can prevent it                         | 2         |
| 2.3 General opinion on green roofs  | 2         |
| 2.4 Limitations of existing literature  | 3         |
| <b>3 Methodology</b>  | <b>3</b>  |
| 3.1 Purpose   | 3         |
| 3.2 Interview   | 3         |
| 3.3 Surveys   | 3         |
| <b>4 Results and analysis</b>   | <b>3</b>  |
| 4.1 Summary and results   | 3         |
| 4.1.1 Surveys   | 3         |
| 4.1.2 Understanding and support of green roofs                                | 4         |
| 4.1.3 When students should start their involvement in maintaining green roofs | 4         |
| 4.1.4 Interview   | 4         |
| 4.2 Analysis  | 4         |
| <b>5 Discussion and implications of findings</b>                              | <b>5</b>  |
| 5.1 General perception of green roofs   | 5         |
| 5.2 Possible implementations  | 5         |
| 5.3 The need for further education  | 5         |
| <b>6 Limitations</b>  | <b>5</b>  |
| <b>7 Conclusion</b>   | <b>5</b>  |
| <b>References</b>   | <b>6</b>  |
| <b>Appendices</b>   | <b>7</b>  |
| <b>A Survey questions</b>   | <b>7</b>  |
| <b>B Interview transcript</b>   | <b>9</b>  |
| <b>C Research project timeline</b>  | <b>10</b> |

# 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 roof 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 Hypothesis

We believe that green roofs are beneficial to the environment, and thus should be implemented in schools. Students are encouraged to play an active role in reducing carbon footprint by taking care of the green roofs.

### 1.5 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.

### 1.6 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% 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 greenhouse 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. Thus, green roof systems can help improve the environment, and slow down climate change.

## 2.3 General opinion on green roofs

Wilkinson et al. (2014) found that 55% 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% 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% 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.

## 2.4 Limitations of existing literature

This existing literature does not focus on students, but on the general population, which does not fully fit our research question. Some of the research is also outdated.

## 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 "1", "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

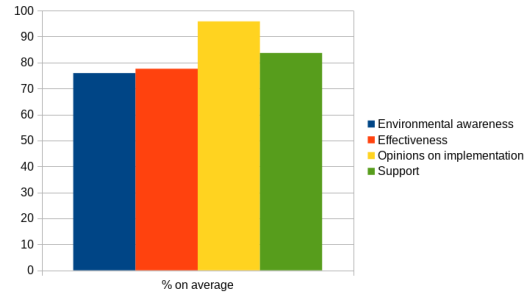


Figure 1: What respondents think of green roofs on average

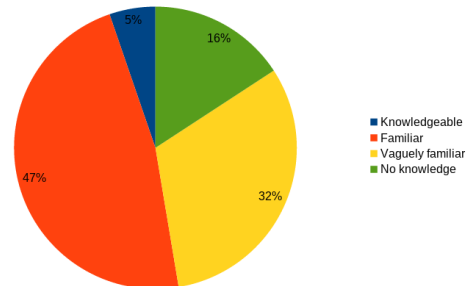


Figure 2: Knowledge levels of respondents

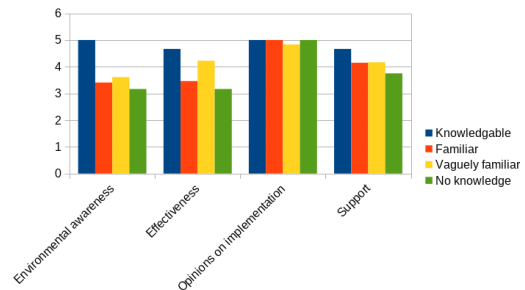


Figure 3: Subgroup analysis of Fig. 1: knowledge of respondents against what they think of green roofs

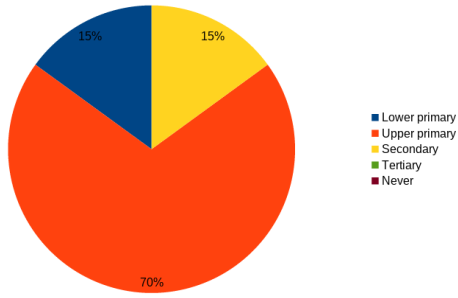


Figure 4: Respondents’ opinions on when students should start getting involved in maintaining green roofs

#### 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 “knowledgeable” about green roofs was the most optimistic, fully agreeing to most of the statements. Furthermore, as is shown in the subgroup analysis 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 1.5, 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.

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.



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                 |

## 5 Discussion and implications of findings

### 5.1 General perception of green roofs

Figure 1 shows that 78% of respondents think that green roofs are effective, and 83% support their use, complementing earlier research in this area as shown in Section 2.3.

### 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.) since they are likely to be less physically inclined, with everyone still keeping to the recommended guidelines by Hui (2010).

### 5.3 The need for further education

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.

Looking back, it would have been advisable to survey parents and school staff as well, as they would be more mature than the students who replied, and also may have another angle to approach this subject from. More possible limitations of green roofs may be explored from their responses, and the demographics of our study could also be potentially expanded.

## 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   | 1                        | 2                        | 3                        | 4                        | 5                        |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| The environment is in an undesirable and adverse situation.                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| There are technologies available that can improve the state of the environment. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Our environment can be improved through the use of green roofs.                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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   | 1                        | 2                        | 3                        | 4                        | 5                        |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Green roof technology can reduce the effect of greenhouse gases on the environment.               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Green roof technology can reduce the cost of running a building.                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Green roof technology, if widely implemented, could help lower temperatures in an area of effect. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Green roof technology can help improve air quality.   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Green roofs are aesthetically pleasing and can improve the visual appearance of a cityscape.      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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?                         | <input type="checkbox"/> | <input type="checkbox"/> |
| Do you think it is a waste of materials to try and build green roofs on buildings?              | <input type="checkbox"/> | <input type="checkbox"/> |
| Do you think it is a waste of effort to try and build green roofs on buildings?                 | <input type="checkbox"/> | <input type="checkbox"/> |
| Would you support the government's hypothetical decision to build green roofs on all buildings? | <input type="checkbox"/> | <input type="checkbox"/> |

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

| Statement  | 1                        | 2                        | 3                        | 4                        | 5                        |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| More green roofs should be implemented in Singapore.         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Green roofs should become standard in Singaporean buildings. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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

- Q11. 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 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     |