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Encouraging Pro-environmental Behaviour Through an Educational Mobile Application: Preliminary Insights from Early Adopters

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mobile application, pro-environmental behaviour, PULA application, technology-enhanced learning, urban education, user engagement

Abstract:

This article aims to explore the extent to which the educational mobile application PULA supports and promotes pro-environmental behaviours, identify the most utilised functionalities by early adopters, and explore the least engaged functionalities. The study employs a quantitative approach based on data collected from the application. The analysis provides a comprehensive understanding of users' experiences and behaviours within the application, contributing valuable insights into its potential to foster pro-environmental attitudes and behaviours. The results suggested that the users, especially women, were generally interested in the learning activities. Pro-environmental transport-related activities were also frequently undertaken by the users. While women tended to split their time into various functionalities of the application, men focused mainly on the transport-related ones. This research contributes to the emerging field of using educational mobile applications for promoting pro-environmental behaviour. The study's focus on early adopters provides unique perspectives on the mechanisms behind behaviour change and offers implications for future interventions. The findings of this study can impact environmental conservation efforts. By encouraging pro-environmental behaviour through an accessible mobile application, a broader audience can be reached and motivated to adopt greener habits. The insights gained from this research can inform the design and development of future applications to foster sustainable practices, benefiting society and contributing to building a more sustainable future.

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Introduction

In the face of escalating environmental challenges, promoting pro-environmental behaviours as a fundamental objective for societies worldwide has become imperative. With the awareness of the adverse impacts of human activities on the natural environment, fostering positive attitudes and behaviours toward environmental conservation has emerged as a crucial step in mitigating ecological degradation (Balundé et al., 2019). The urgent need to address climate change, biodiversity loss, and resource depletion calls for innovative approaches to engage individuals in pro-environmental actions.

Technology, particularly mobile applications, presents a promising avenue to encourage and empower individuals to adopt pro-environmental behaviour. Educational mobile applications (Balińska, 2021; D'Arco & Marino, 2022), like the one examined in the presented study, offer a unique opportunity to deliver informative content, raise awareness, and facilitate behaviour change. Such applications can be powerful tools to inform users about the environmental consequences of their actions, provide practical tips for sustainable living, and track their progress in adopting greener habits (Balińska, 2021; Ouariachi, et al., 2020). By leveraging the potential of educational mobile applications, we can target a broad audience and effectively disseminate pro-environmental knowledge.

Encouraging pro-environmental behaviour goes beyond individual actions; it is a societal responsibility and a critical step toward building a sustainable future. Educational mobile applications in general provide a dynamic platform to bridge the gap between knowledge and action, making it feasible to motivate individuals to embrace environmentally friendly practices and collectively contribute to preserving our planet. Mobile applications hold immense potential in promoting and supporting pro-environmental behaviours among city residents. They can increase awareness and educate users about environmental protection issues, track and monitor ecological behaviours, shape positive habits, and foster social collaboration and engagement (Jeng et al., 2010; Xiao et al., 2022). However, their success depends on appropriate design, scientific research findings, and community engagement in environmental conservation efforts.

An example of such a mobile application is PULA. It has been developed by a consortium of Polish and Norwegian researchers in the research project 'Greencoin', funded through the Iceland, Liechtenstein, Norway grants, and the state budget of Poland. The consortium was assigned the challenge of developing a new solution or service to improve the quality of life of inhabitants of urban areas and responded to this by developing a concept for a community currency designed to promote sustainable everyday practices. PULA is a mobile application where citizens can register their pro-environmental actions, spanning from everyday actions such as commuting by bicycle to larger activities such as developing a micro-garden. Photos and Global Positioning System (GPS) are used to confirm the validity of the actions. The registered and confirmed actions release digital coins to the user's account, and these coins can be exchanged in goods, services and activities offered by local enterprises and organisations. The users can also earn coins by taking educational quizzes on environmental issues.

PULA is designed to cultivate a geographically bounded network of citizens and enterprises. It is currently being tested in the city of Gdańsk, Poland, but can also be adapted to other cities. By addressing local issues of sustainability, the application does three things. First, it steers clear of the politicised discourses that are often evoked when global environmental issues are addressed (see Forchtner, 2020 for discussions of environmental discourses in politics). Second, individuals can respond with passivity when confronted with the threat of global environmental issues, whereas local challenges can be easier to relate to. Focusing on local, tangible issues and rewarding everyday actions can be a way of easing passive or disillusioned citizens into environmental engagement that may grow to cover more complex and less tangible issues over time. Third, keeping a local focus gives the opportunity for developing a local network of enterprises, organisations and citizens that can be a resource for the sustainable transition of the city.

In the current paper, we will present the initial results of the pilot testing of the application among the residents of the city of Gdańsk. Our analysis aligns with the Diffusion of Innovation Theory (DIT; Rogers, 2003). According to DIT, the innovation, which is understood as a novel idea, project or practice, creates uncertainty regarding the consequences of its adoption. The process of diffusion pertains to the communication of the innovation to the social system, and consists of the subsequent stages of: knowledge (disseminating knowledge about the innovation, which success relies on the characteristics of the decision-making person), persuasion (that is based on the assessment of the relative advantage of adopting the innovation, its compatibility, complexity, trialability and observability) and decision regarding the adoption or rejection of the innovation, implementation and confirmation. By exploring the initial experiences with the application of the pilot users of PULA, we can assess the quality of the persuasion stage and observe the tendencies on the decision stage to better plan the final implementation and confirmation stages of diffusion.

The technology-driven approach to pro-environmental action has the potential to transcend geographical barriers and engage individuals from diverse backgrounds in collective efforts to safeguard the environment. Moreover, the insights gained from studying early adopters of such applications as PULA, can shed light on the mechanisms behind behaviour change and help optimise future interventions for more significant impact (Boncu, 2022).

The current study will present the research findings conducted during the implementing of the PULA project. Based on the initial literature and cases review, we formulated the following main research question (MRQ): How do educational mobile applications contribute to the promotion and adoption of pro-environmental behaviours among urban residents, considering the extent of their effectiveness, preferred functionalities by early adopters, and least engaged functionalities?

Related Works

In the face of mounting challenges related to the degradation of the natural environment, promoting pro-environmental behaviours has become a paramount goal for societies worldwide. Our current research builds upon a theoretical foundation that also draws from our previous articles. This previous research has served as a basis for our present study. We explored the potential of promoting pro-environmental behaviours through an educational mobile application and gained initial insights from early adopters (Obracht-Prondzyńska, et al., 2021).

Moreover, our theoretical framework also aligns with our earlier study where we investigated the development of the Greencoin information system. This system aims to support urban adaptability and climate change mitigation through the integration of community currencies and technological advancements. The analysis of 120 social currencies and information systems contributed valuable data to shape the framework of the Greencoin IS, which involves applications, functionalities, and technological aspects for fostering social engagement and eco-inclusion (Obracht-Prondzyńska, et al., 2022).

As we delve into the exploration of educational mobile applications' impact on pro-environmental behaviours among urban residents, our research benefits from the insights and methodologies established in these prior studies. The interconnectedness of these studies underscores our commitment to advancing knowledge in the realm of technology-driven solutions for sustainable urban development and behaviour change (Duda, et al., 2022; Zawieska, et al., 2022).

Understanding the psychological aspects of attitudes and behaviour change towards pro-ecological stances is essential for practical environmental conservation efforts. In today's world, faced with escalating issues related to environmental degradation, promoting pro-environmental behaviours among city residents has become an exceedingly crucial goal. In this regard, applications can be pivotal in supporting and propagating pro-environmental attitudes within urban communities (Boncu et al., 2023).

A significant area where applications can support and promote pro-environmental behaviours is increasing awareness and educating city residents about environmental protection issues. Interactive mobile applications can inform users about the impact of their daily actions on the environment and present specific and realistic ways to reduce their ecological footprint. Such applications can reinforce pro-environmental attitudes by delivering credible scientific information (Jeng, Yu-Lin, et al., 2010; Ahn, 2022). Moreover, mobile education allows for flexible knowledge transfer, enabling learning in a variety of situations. Dividing educational content into short and attractive fragments provides an opportunity to take advantage of the user's fragmented time, thus responding to the needs of fast-paced life (Liang et al., 2018).

Tracking and monitoring users' ecological behaviours through applications can also motivate them to make more sustainable choices. Applications can be used for sustainability education, energy reduction, transportation, air quality, waste management, and water conservation (Douglas & Brauer 2021). Introducing these applications allows city dwellers to analyse their consumption habits and make pro-environmental decisions.

Additionally, such applications can offer reward systems and challenges, providing additional motivation for adopting sustainable actions (Giancola et al., 2021).

Mobile applications play a role in shaping and solidifying positive habits among city residents. Through reminder features, applications can assist in maintaining pro-environmental habits in daily life, such as using public transportation, avoiding plastic packaging, or reducing food waste. Repeating these behaviours can contribute to their integration into users' everyday lives (Balińska et al., 2021; Boncu, 2022). These considerations inspired us to formulate the next detailed research question:

- RQ1: To what extent can the educational mobile application support and promote pro-environmental behaviours among city residents?

The utilization of sustainability apps for promoting pro-environmental behaviour has gained attention as a means of fostering engagement and change. In a study by D'Arco & Marino (2022), they examined the relationship between awareness of consequences, ascription of responsibility, personal norms, and environmental citizenship behaviour. The study also highlighted the moderating effect of sustainability app usage on these predictors of environmental citizenship behaviours. Our research contributes to this field by shedding light on the potential of mobile apps to stimulate environmental citizenship behaviours.

Similarly, Ouariachi, Li, & Elving (2020) explored the role of gamification in influencing pro-environmental behavioural change. They identified and analysed various pro-environmental gamification platforms, using frameworks like the Octalysis Framework and the Climate Change Engagement through Games Framework. Out of 181 cases, two platforms, namely SaveOhno and JouleBug, were recognized as best practices with the potential to effectively engage users in pro-environmental behavioural change. The study emphasized the importance of attributes such as meaning, ownership, social influence, believability, challenge, and credibility in designing successful gamification platforms.

Combining these findings, the following question emerges:

- RQ2. Which functionalities of the application were most enthusiastically utilised by the early adopters?

Exploring the potential barriers to engagement, the study by D'Arco & Marino (2022) investigated the least utilised functionalities of sustainability apps within the context of promoting environmental citizenship behaviour. Meanwhile, Ouariachi, Li, & Elving (2020) examined gamification platforms and their effectiveness in driving pro-environmental behavioural change. Through the analysis of two different frameworks, the study identified core elements contributing to the success of gamification platforms. In light of these findings, this question emerges:

- RQ3. Which functionalities of the application were least engaged with by the early adopters?

Positive habits could be sustained by a sense of social acceptance and affiliation related to the activity. That is why applications that incorporate a social media component can encourage social collaboration and engagement. Creating platforms that facilitate the exchange of ideas, experiences, and achievements related to environmental conservation can contribute to building a solid pro-ecological community within the city. Moreover, social media applications can aid in organising environmental campaigns, making them more accessible to residents and increasing their involvement in environmental protection initiatives (Han et al., 2018; Boncu et al., 2023).

The PULA application has been designed to incorporate these insights about the mobile applications' potential. However, how do the pilot users assess its quality?

Based on these considerations we formulated the following research objectives:

1. To examine the extent to which the educational mobile application PULA can support and promote pro-environmental behaviours among city residents.
2. To identify the PULA application functionalities that the early adopters most enthusiastically utilised.
3. To explore the functionalities of the PULA application that were least engaged with by the early adopters.

Methodology

Procedure, Analysis, Participants

To answer the research questions, we use a quantitative approach based on data collected from the application PULA (Figure 1). This methodology aims to provide a comprehensive analysis of the users' experiences and behaviours within the educational mobile application, allowing for a deeper understanding of the impact of the application on fostering pro-environmental attitudes and behaviours among city residents (Leavy, 2022). The data collected is analysed in line with the Diffusion of Innovation Theory (Rogers, 2003). The research will consider the following aspects:

— Temporal conditions: investigating when and for how long city residents use the application (e.g., during their commute, while on a walk) and their specific activities.
— Functional considerations: analysing which features of the application early adopters intended to utilise and how they interacted with those features.
— Individual factors: understanding the characteristics of individuals willing to use the application and how they choose to engage with it.

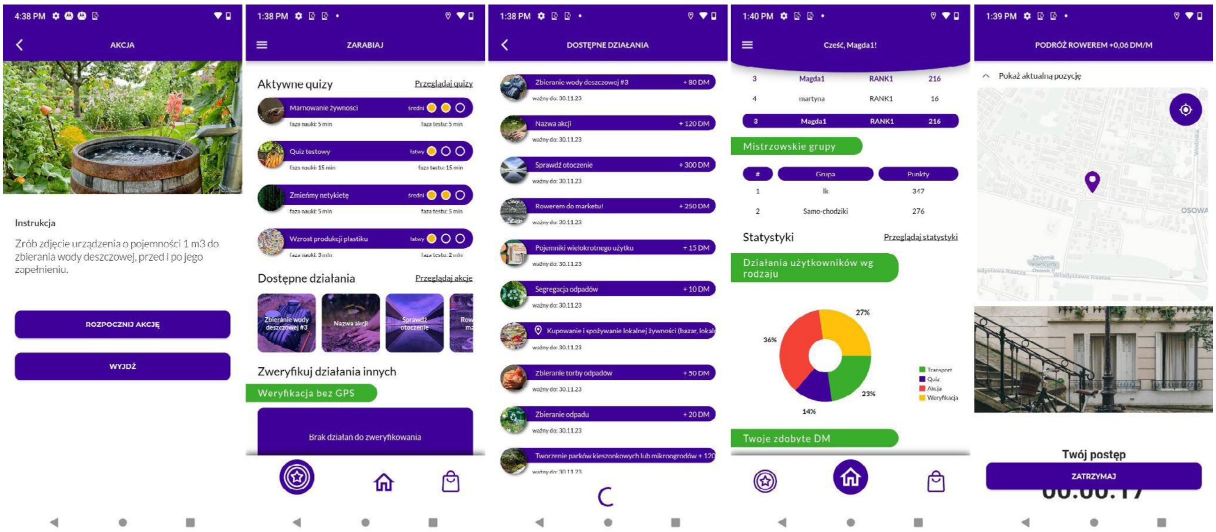

Figure 1. PULA application screenshots

At the recruitment stage, the researcher team contacted business and science institutions with an open call for voluntary participants to test the early version of PULA pro-environmental application. The study involved 29 participants, including 20 women and 9 men. The distribution of participants by age range is shown in Figure 2. The largest proportion of the group testing the app (44%) were young people in the 18-25 age range. These are active employees and students who are open to doing things for the environment and have expressed a willingness to test the PULA application. The application was tested for two months (9 weeks), from 6 of May till 9 of July 2023. Data gathered from this period were analysed in the presented study. All participants provided informed consent for testing the application and participating in the study. Contact data to the researchers was provided before the start of the study so that the participants could pose questions and ask for the study results anytime.

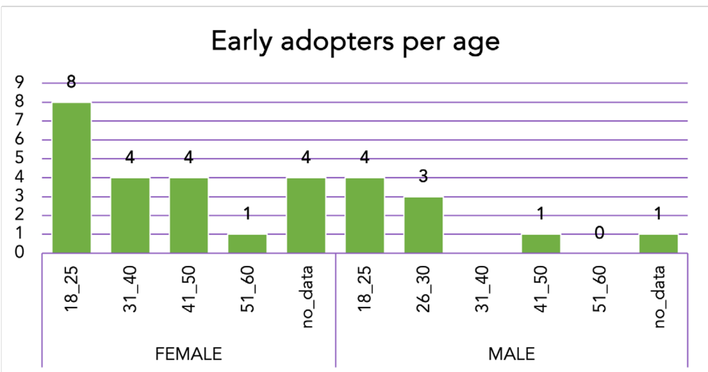

Figure 2. Study participants per age

Technical Settlement

The PULA system is built based on the 3-Tier System Architecture which consists of Client Applications, Application Server and Database. The users were divided into two groups: Mobile Application Users and Administrators. The Mobile Application Users can access the system with their mobile devices operating on Android Operating System and iPhone Operating System (iOS). Ahead of accessing the application Mobile Users are required to register their account with an email address as identification. To use all of the system functionalities, Mobile Users have to give permission to access their camera, files and location module. The Administrators can access the Administration Panel via any web browser, upon invitation by the system operator. Administrator Panel allows management of users, partners, actions, rewards, achievements, challenges, push notifications and QR (quick-response) codes functionality. The activity data of all the users, including points earned or spent, is stored in Structured Query Language Database for further analysis and is available to advanced users or system management, but not available to the Administrator.

Results

Overall Evaluation of the Application

The majority of participant activity was observed in two categories: transportation and participation in quizzes. Transport-related activities (choosing walking, cycling or public transport over driving) for men accounted for 89,1% of all activities, while participation in quizzes accounted for 24,9%. Similarly, transport-related activities for women accounted for 63.1%, with participation in quizzes accounting for 70.9%.

Interest in quizzes activity over time revealed notable fluctuations, supposedly related to the timing of new quizzes that appeared in the application. Three periods of an increased quizzes activity could be distinguished. The first three weeks show an upward general trend, the sixth and seventh testing weeks are the most active period and the ninth and tenth weeks of the pilot phase show a clear decreasing trend. Starting from the second phase a clear trend of decreasing activity is observed.

The male group was active in the quizzes category in the first half of the pilot testing phase, and completely stopped this activity in the second half. In contrast, the female sample group was active during the whole testing period and increased their quizzes activity in the second half of the research phase, confirming general interest in knowledge gaining among females through the means of the application. Interest in news, challenges and QR codes was present through the testing period, yet demonstrated several brief bursts and decreases of activity with no clear overage trends to be distinguished.

The female group demonstrated an overall higher activity and persistence in earning coins for all the functions studied except the welcome survey. In total, women earned approximately 54% more coins than their male counterparts. The most active age group ranges between 51- and 60-year-olds, with 18-25 year-olds and 31-40 year-olds being consequently the second and the third most active age groups. However, these results are of limited representativeness as there was one exceptionally active participant in the 51-60 age group whose results diverged from the rest of the group.

Friday was the most popular day in terms of the daily activities during a week, while, in general, during working days more actions are undertaken. In general, PULA application use was rather stable during the researched pilot period. The use of the PULA app changed over time. The highest user activity was observed during the second and sixth weeks of using the app, while the lowest activity was observed during the last three weeks of the pilot period. A particular time of year, the end of the academic year (exam session for higher education students) and the beginning of the holidays (start of the holiday season), may also have contributed to the decrease in activity in the last three weeks.

Evaluation of Particular Features

In terms of differences in activities by gender, the female sample group demonstrated highest activity and interest in quizzes, with transport being the second most popular activity, while males were the most engaged in transport activities. Since transportation allowed the fastest way to score points, these results suggest that for men, scoring points was more significant in their app usage strategy, whereas for women, the opportunity to learn while using the app was an equally important value. Both groups earned more points than they spent (approx. 45% for males and approx. 25% more for females). The results suggest that over time the rewards were either less appealing or outside their area of interest, which affected their motivation and incentives to use the app over time.

Based on the results of earned coins by age and function (see Figure 3), the most popular function was transport among all age groups, with the 51-60 age group being the most active in the researched sample, and 18-25 age group – being the second most active in the transport function use. The second most popular feature was a feature called 'product', which was particularly popular with 18–25-year-olds and 31-40 year olds, but this feature related to exchanging earned coins for vouchers (spending coins), not earning coins. The third most popular category in terms of earned coins was QR code, mostly used by 51-60- and 18–25-year-olds. Unsurprisingly, earned coins for the welcome survey were evenly distributed among all researched age groups. When it comes to a summary of all activities by age groups, the most active age group was between 51- and 60-year-olds, with 18-25 year-olds and 31-40 year-olds being consequently the second and the third most active age groups. The least active group in the researched sample was 26–30-year-olds.

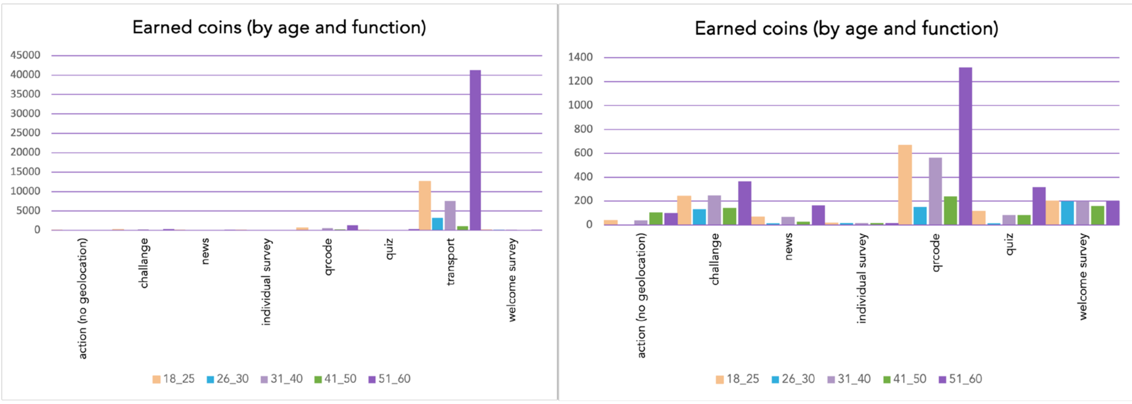

Figure 3. Results of earned coins by age and function (without and with transport)

The research results suggest that overall, people earn above 50% more coins than they spend. The 18-25 age group demonstrated the highest spending to earnings ratio (approx. 10500 coins spent to 21500 coins earned). The second age group is between 31- and 40-year-olds (approx. 6000 coins spent to 14500 coins earned). Other age groups, namely 51-60-, 26-30- and 41–50-year-olds, have not spent the coins they have earned, with the oldest age group of 51-60 year-olds earning the highest absolute number of coins without spending them.

The highest activity of participants in doing learning activities (Figure 4), in particular – solving quizzes, was registered on Fridays, while the lowest activity was registered on Saturdays. In terms of time of day, participants were most active reading news and solving quizzes at 10am (suggesting the time of their first break at work), slightly less so between 1pm and 2pm (lunchtime), 4pm (activity on returning home from work/university) and 7pm. The lowest learning activity was recorded at 12pm, between 1pm and 2pm, then between 8pm and 10pm and during the night.

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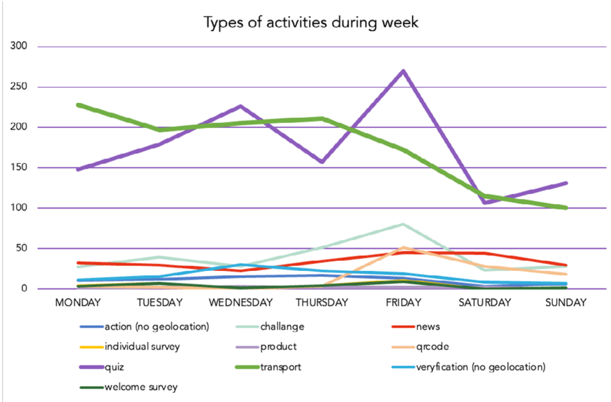

Figure 4. Types of participants' activity during week

While in general both genders' activities were reduced on the weekends for the absolute majority of researched age groups, two age groups revealed application activity on Sundays, namely: males between 26 and 30 years and females between 51 and 60 years. When we compare those results with types of activities during a week, quizzes and challenges seem to be the activities that receive an increased interest on Sundays. The least active groups for both genders were 31-40- and 41–50-year-olds.

The learning activity is consistent with overall application usage activity (the highest during the second and sixth weeks of using the app, while the lowest during the last three weeks of the pilot period). An interesting observation, however, is the difference in activity by gender. While women participated relatively regularly in reading news, short articles and solving quizzes, men almost completely abandoned these activities from the fifth week of the pilot.

The most active age group was 51–60-year-olds. Despite the general downturn trend in the two last weeks of the research study among the majority of age groups, this group demonstrated an overall increase during the last pilot phase. The second most active age group was 31–40-year-olds, which had a general high interest during the first three weeks of the pilot study and a small increase during the seventh week. Yet, the general activity of this group was reduced in the second half of the testing period. 18–25-year-olds was the third most active group with a rather stable activity level during the whole testing period, yet with a small declining trend in the last two weeks of the study. The next active group between 26- and 30-year-olds had an increased registered activity during the seventh, eighth and ninth weeks, but reduced their activity to a minimum after the ninth week. Finally, 41–50-year-olds were the least active group during the pilot phase. Still, their activity was notable during the last week of the testing period.

In terms of general user activity during the whole research period, the PULA application use was rather stable over the 9 weeks testing phase with a general downturn trend during the last three weeks of testing phase (see Figure 5). While Challenge use is characterised by small fluctuations overlapping with weekends and academic session period, an additional tendency is also visible, namely: a drop in product use (spending earned coins) correlates with an increase in challenge activity. The last trend could be explained by overall limited time in a daily use of the PULA application, suggesting that if more time is reserved for a particular activity, that would lead to less time spent on the other activity.

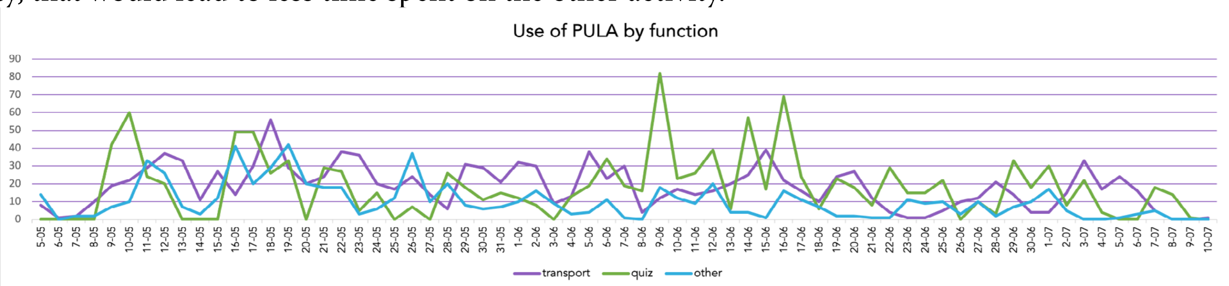

Figure 5. Use of PULA application by function

Evaluation of Spatial Aspects

The use of public transport is the most frequent among almost all the age groups except 41–50-year-olds, corresponding to more than 70% of all actions in the transport category by distance. The second most popular action is walking, while biking was the least popular among all the researched age groups. The difference is visible when it comes to the gender preferences for transport actions: public transport was the most popular among females, while males preferred walking over public transport or biking. It is also notable that despite being the most preferred activity among males, in total they earned less coins for this category than females (7200 coins against 9010 coins in total).

More coins were earned in transport category between 2pm and 5pm (typical lunch breaks and afterwork transport back home). There were three peaks in spending coins in the product category: from 6am to 8am (time before work, probably on a way to work/university), from 8am to 10am and the highest one – from 6pm to 9pm (dinner and after dinner time). The most popular days to earn coins for transport were Thursday and Saturday, for QR codes – Friday, and again Thursday – for Product category. The least number of coins was received on Sundays.

Public transport leads when it comes to the distance covered, but walking leads if total earnings by type are concerned. Walking activity leads when it comes to hourly activity by type, with two daily picks at 9am and 15am (possible correlation with the travels to and from work/university). The second most popular activity by hours is public transport that has its daily picks at 8am, 10am and the highest being 4pm. The least popular activity by hours – biking – noted its daily picks at 8am, 11am and between 4pm and 6pm.

In general, females accumulated more total hours dedicated to transport activity than males, and demonstrated a slight increase during Sundays, while males were least active during Sundays, when it comes to transport activities. Additionally, 51–60-year-olds and 18-25 year-olds were the most active both during Sundays and in terms of total amount of coins earned for transport. The third group in terms of earned coins for transport is 31–40-year-olds, while 41-50 year olds were the least active group in this category.

Transportation Features

Since transportation is the most used function among the early adopters we will focus on these results. The most interesting results concern the differences between female and male users, while age is less significant.

What we have learnt from the evaluation of the application is that men are more likely to choose transportation over other functions. We assume this is due to the competitive attitude as the transportation function allowed to earn more credits. Females on the other hand used the transportation function with the same frequency as other options available in the application. This can be observed based on the charts below (Figure 6).

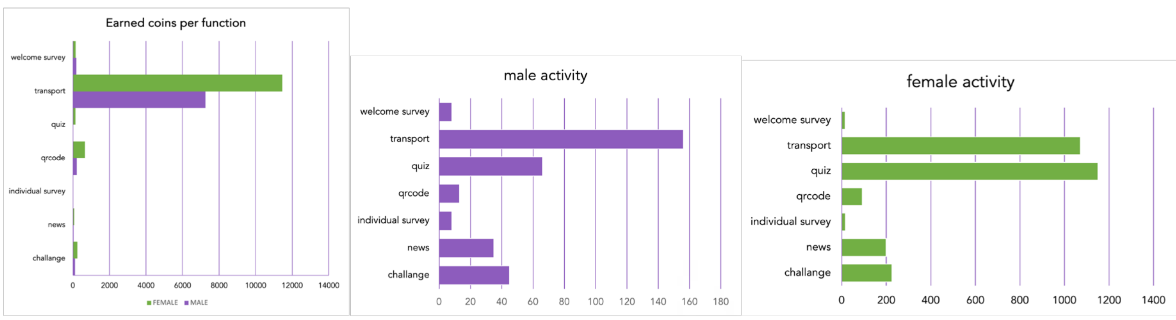

Figure 6. Earnings by gender a function

The activity differentiated also over time. With the time flow we observed that women use the application to earn based on transportation function with the same frequency as at the beginning. The activity of men drops over time (Figure 7). However, despite the attitude pushing men to use more profitable functions, when considering average results, women earn more when using transportation functions (Figure 8).

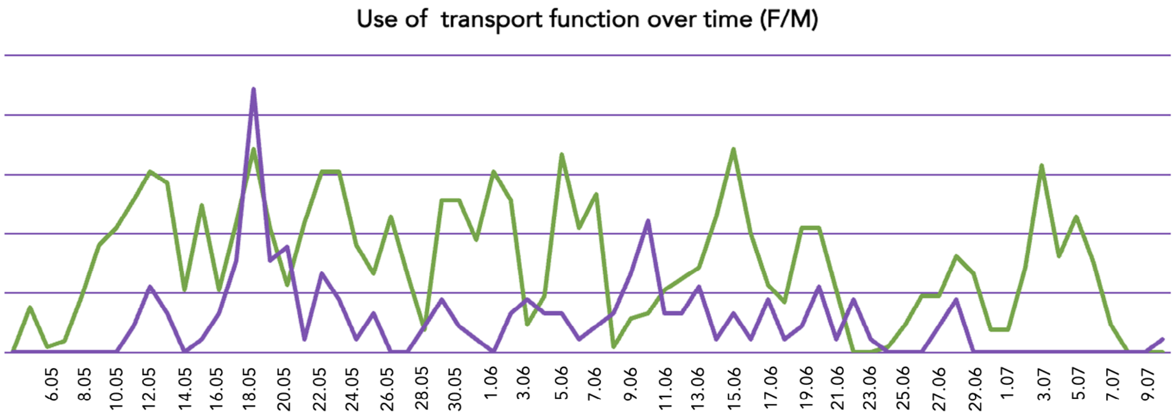

Figure 7. The use of transportation functions by female (green) and male (violet)

The results suggest women are more likely to use the application to learn and shape good habits instead of focusing on earnings. This can be observed how the activity is changing during a week or day. While men's activity drops with the week flow, the women become more active during the weekend and at the beginning of the week. Women also use the application when the occasion occurs – e.g. when commuting to work while men use every opportunity to earn as their day activity is more balanced. Figure 3 suggests that generally the application plays an important role when performing daily duties. What can be found as a valuable impact on users' habits.

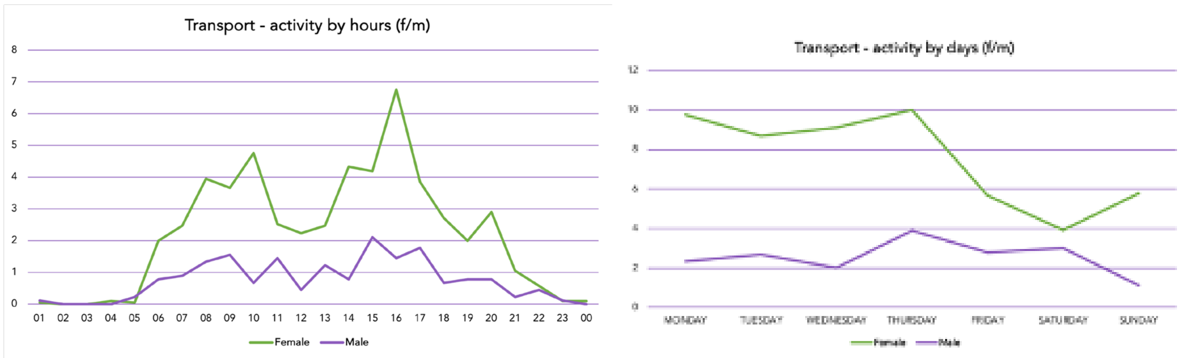

Figure 8. The use of transportation functions by female (green) and male (violet)

The critical part of the use of the transportation function is where it is used. Based on the analysis of GPS data collected with the application, we can observe that the early adopters used the application in the main core of the city where the application was tested (Map 1). This site can be recognized as well connected, with cycling infrastructure and more walkable compared to other districts. The challenge is how to encourage users of the application to change for public transportation or cycling within car-oriented areas. Map 2 also brought to our attention that early adopters are more likely to use the application in the afternoon and in the evening, when they are probably less in rush.

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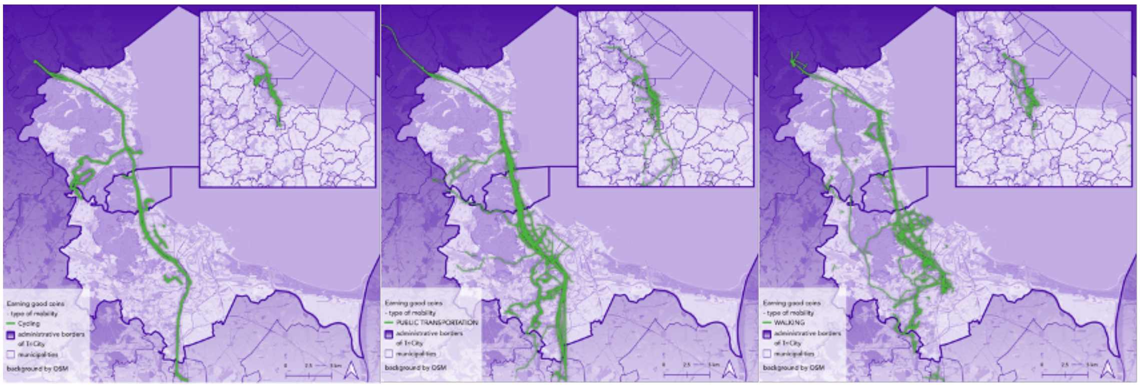
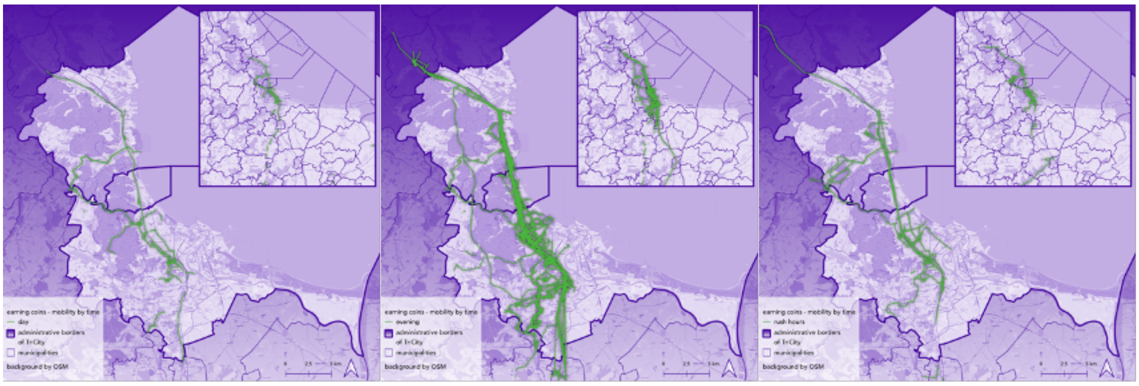


Map 1. Mobility of early adopters depending on the commuting time

Source: PULA data, OpenStreetMap, Authors' own elaboration



Map 2. Mobility of early adopters by time of a day

Source: PULA data, OpenStreetMap, Authors' own elaboration

As the Map 1 and Figure 9 present – public transportation is the most popular type of chosen activity by early adopters, while they earn more when walking. This is due to the decision that the earning should depend on how much energy is needed to commute. This can be however differentiated depending on the size of the city.

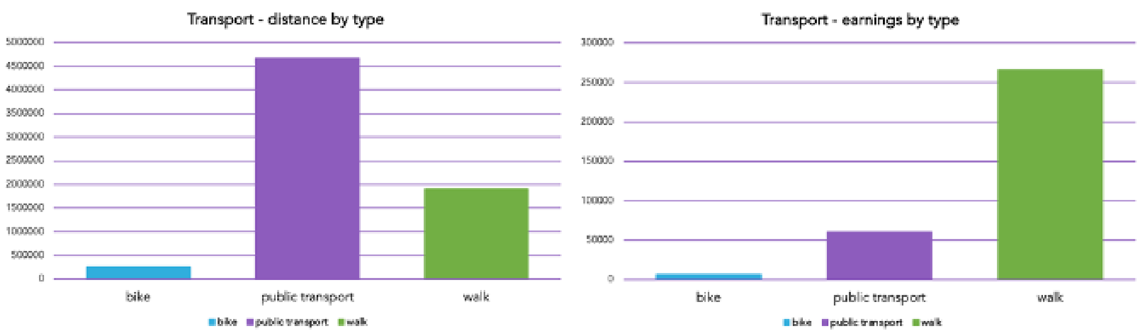
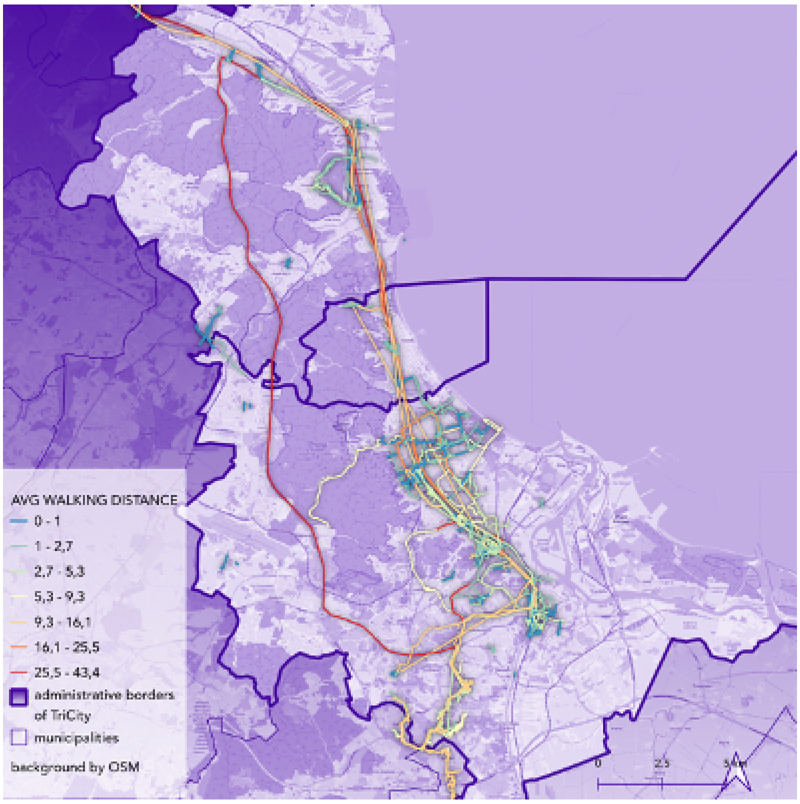


Figure 9. The average distance by functions and earnings

The design of such a solution also requires a lot of attention on the weak points allowing the users to cheat. Our lesson learnt is that the users will immediately switch to more profitable options and forget about the initial idea of pro environmental behaviour. This can of course differ depending on the cultural background, but the designers should nonetheless focus more on the limitations. Map 3 proves that some users choose walking functions (as it was more profitable) while commuting by car. The red colour on Map 3 (presenting average distance of the users) is the ring road of the city where pedestrians are not allowed. We solved the issue by adding the speed limit for each type of mobility, however all other functions need to be evaluated for the cheating options.



Map 3. Average walking distance with Pula app

Source: PULA data, OpenStreetMap, Authors' own elaboration

Discussion

The promotion of environmentally friendly behaviour remains one the most important current goals of urban areas. In this paper it is analysed how the introduction of the novel mobile application can support and promote such activities.

During the analysis, it was confirmed that by exploiting the educational potential of mobile apps, it is possible to disseminate environmental knowledge to a wide audience, as well as provide information on sustainable living practices or track users' progress and changes in their habits (Balinska, 2021; Ouariachi et al., 2020). Users of our app showed high interest in learning activities. The quizzes were aimed at imparting knowledge on environmental issues and implementing good habits in daily life. Our research confirms previous findings (Jeng, Yu-Lin, et al., 2010; Ahn, 2022) that the app can be an effective tool in shaping attitudes by conveying reliable and up-to-date knowledge. During the study, various forms of quizzes were tested. Users preferred shorter and more frequent quizzes. Short forms, in which educational materials of no more than 1,000 characters were published several times a week, were the most popular. Longer materials (more than 2,500 characters) elicited lower engagement. This confirms the need to divide the course into microlearning modules suitable for mobile learning, as mentioned by Liang et al. (2018). Dividing the material into fragments makes it possible to undertake learning in different contexts, breaking down the limitations of time and space, responding to the needs of a fast-paced life.

The results of this study confirm that interests of learning activities differ between men and women. Women showed higher interest in these activities. The reasons for this disparity are complex and can be explained in different ways. According to various studies women are more focused on pro-environmental behaviour, are more likely to adopt pro-environmental attitudes and base them on their values and are more likely to participate in pro-environmental activities, which can be explained by gender socialisation theory (Vincente-Molina et al. 2018; Tikka et al. 2000; Zelezny et al. 2000). Greater sensitivity to environmental aspects may have influenced the motivations of different genders in using the app. Women, more focused on the environment, took up activities to gain new knowledge and make changes in their habits. As far as educational impact is considered, differences in the use of educational app functionalities have been observed between women and men. Women consistently used the educational functionalities throughout the monitoring period, while men only did so in the initial weeks of the pilot phase.

Several previous research have indicated that digital tools have the potential to enhance pro-environmental actions (Soliman et al., 2017) and that a technological approach could break geographical and environmental barriers by connecting multiple users from diverse groups within its system (Ozdamli et al., 2011). However, the motives behind pro-environmental behaviours and their diversity cannot be easily predicted. None of the motives are universal or applicable in all conditions or situations (Young, 2000), therefore, it is worth ensuring a variety of ways to engage users in eco-friendly behaviours in the application.

This was also confirmed by the results of our study. The results suggest that application tools can influence the educational aspects of pro-environmental actions and formation of new habits, however in a limited way. For instance, our findings show that transport-related activities were the most frequently used within the application. The users might thus prefer to focus on every day and mandatory activities like commuting rather than finding spare time for new types of actions. The use of local public transport (beyond walking tours and cycling) gained the most interest and accounted for 70% of all distance transport actions, and during peak hours. The evidence supports the claim that application users travel in a less energy-consuming manner and provide greater support for urban transportation (Shaheen at al., 2016). It was also observed that women split their time in the application between various actions, while men focused their attention mainly on transport. It is worth noting that these actions were the highest scoring/rewards within the application, suggesting the significance of point values assigned to subsequent activities. It was observed also that individuals who regularly use public transport rarely attempt to use other alternative types of transport such as cycling or walking. However, drawing conclusions from the gathered data is difficult due to the small sample size and limitations in the data set.

It is worth referring to numerous separate applications that record cycling or walking routes, to which users may already be more accustomed. An interesting starting point for further investigation is the analysis of the urban transportation infrastructure and its impact on the choice of preferred mode of transportation by local residents. Consequently, further research on transportation analysis is planned in order to derive clear recommendations. The remaining challenge is that the pro environmental activity is limited to the area of the city that is well-served, e.g., by public transportation. This confirms that the built environment has a significant impact on residents' behaviours (Handy et al., 2002).

Our results partly confirm that applications can be used for tracking various pro-environmental habits (Douglas & Brauer, 2021). However, the results show that effective tracking of user behaviour should not require special effort. The successful activities were mainly transportation-related, and therefore required relatively low effort from the user. Therefore, basing tools on self-reporting results in a lack of data on whether users are actually not engaging in certain activities, or simply not reporting them in the app. The lack of reporting on certain activities may be due to users forgetting about the tool, being reluctant to make the extra effort, protecting their privacy, or the existence of competing tools that track user behaviour and are more attractive to them (e.g., sports apps). Moreover, offering rewards for achievements introduces the risk of abuse of the system. During testing, attempts were made to reduce the possibility of cheating (such as setting speed limits in the transportation module). This change increased the incidence of errors and showed inflexibility to a variety of forms of transportation (e.g., light rail exceeded speed limits, which were introduced to prevent cars from moving using the app).

In conclusion, our analysis highlighted that the functionalities related to knowledge and learning, as well as encouragement to employ environmentally friendly forms of transportation are the most popular activities. It can be assumed that highlighting and rewarding these activities could be most efficient in the persuasion stage of diffusion of innovation such as the PULA application (Rogers, 2003). Presumably these activities should be highlighted to enhance the adoption of the application by potential future users, as well as be further developed to boost the subsequent stages of the diffusion of innovation.

Conclusions

In summary, our research answered four questions. The study found that educational mobile apps, such as the PULA application, can promote pro-environmental behaviours among urban residents. The most effective functionalities were related to transportation activities and quizzes. Users were more engaged in transportation-related activities, such as choosing walking, cycling, or public transport over driving. Quizzes were also popular for learning about environmental issues and forming habits. However, engagement decreased over time, and there were limitations in terms of self-reporting behaviours (MRQ).

The educational mobile application, PULA, was found to effectively support and promote pro-environmental behaviours among city residents. It facilitated learning about sustainable habits and encouraged users to choose eco-friendly transportation options. The app's gamification mechanisms, like quizzes and earning coins, positively influenced user engagement in pro-environmental activities (RQ1). The most enthusiastically utilized functionalities by early adopters were related to transportation activities (choosing walking, cycling, or public transport) and participation in quizzes. These activities accounted for a significant portion of user engagement, indicating a strong interest in environmentally friendly transportation options and knowledge acquisition (RQ2).

The study did not outline the features which received the least engagement from early users. The functions created in the app outside of transportation and education appeared to elicit minimal interest from users, likely due to their less appealing nature and lack of user-friendliness (RQ3).

The novelty of the research comes from testing in practice theories on influencing human pro-environmental behaviour through mobile tools, using gamification mechanisms. This makes it possible to identify both the opportunities and limitations of using such applications. Moreover, it gave conclusions about human behaviour in interactions involving the environment, the individual and the application.

There are some limitations of our study that may require further research. It should be noted that the participants' pool had a closed character, with a limited number of individuals who registered for the pilot program (*N*=29). However, such small research sample was purposely selected to test the application among active and committed people interested in pro-environmental activities. The study lasted 64 days, during which time changes were made to the application as it was under development. The results also refer to PULA application only and do not test alternative mobile apps, which prevents drawing conclusions about the relative efficacy of the PULA application compared to other pro-environmental apps.

Conducting quantitative research should be complemented in future studies with a qualitative approach to learn about the user's perspective, motivations, feelings and opinions. The role of technology in environmental efforts seems promising, so future research is needed on a larger group and over a longer period, using new technologies and functionalities that optimise the effectiveness of mobile apps in transferring knowledge and supporting sustainable habits.

The results can be used for future applied research related to the use of technology in shaping pro-environmental attitudes. Beneficiaries of the research results are decision-makers and city representatives who are considering the use of mobile tools to encourage residents to change their habits, take environmentally friendly actions and develop their ecological knowledge. In addition, the results presented show behavioural differences due to demographic factors and environmental conditions that influence the choice of sustainable activities like choosing sustainable modes of transportation. This opens the possibility to analyse mobile applications not only as tools to shape behaviour, but also to measure it, analyse and plan urban interventions that could support sustainable choices of city users.

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