Exploring the World through Small Green Steps: Improving Sustainable School Transportation with a Game-based Learning Interface

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ABSTRACT
In this paper, we present a playful digital activity for primary school classrooms that promotes sustainable and active mobility by leveraging the daily journey to school into a collaborative educational experience. In the class game, stretches of distance travelled in a sustainable way by each child contributes to the advancement of the whole school on a collective virtual trip. During the trip, several virtual stops are associated with the discovery of playful learning material. The approach has been evaluated in a primary school with 87 pupils and 6 teachers actively involved in the learning activity for 12 continuous weeks. The findings from the questionnaires with parents and the interviews with teachers show a positive effect in terms of children’s behavioural change as well as educational value. Indications on the use of class and school collaborative gamification activities for supporting sustainable behavioural change are discussed.

CCS CONCEPTS
• Human-centered computing → Empirical studies in HCI;

KEYWORDS
Gamification for behavioural change; Children’s environmental education; Sustainable mobility; Interactive learning interfaces.

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is correlated with higher levels of activity [1] and children tend to carry their road user habits into adulthood [6]. Parents’ motivations range from perceived lack of safety to practical considerations such as convenience and time saving [24]. Plenty of grassroots and participatory initiatives are being launched at a local level providing bottom-up solutions supporting children’s freedom of movement (e.g., walking buses, bike-trains, volunteers at crosswalks, ride-sharing among parents, and similar). Still, any innovative and costly programme introduced from the top down by cities to increase traffic safety and children’s independent mobility is more likely to succeed if combined with initiatives aimed at changing parents’ and children’s attitudes, and at increasing citizens’ awareness towards this problem [6].

The research question of this work is assessing the feasibility of a seamless integration of an approach to motivate and sustain behavioural change in an educational setting. Kids-Go-Green aims at raising the awareness and changing the behaviour of children and their families with respect to active and sustainable mobility habits by leveraging the potential of gamified educational initiatives. With Kids-Go-Green the whole school can take part to a collaborative educational game that delivers the value of collectively changing mobility habits. Sustainable school trips by each kid contribute to the progress of the whole school in a virtual path mapped onto the real world. As the journey progresses, an interactive digital map of the territory shows the accomplishments of the school, and the arrival to intermediate stops. Multimedia educational material is associated to each of those stops, making each achievement an opportunity for in-class learning. Kids-Go-Green has been used in a primary school in Trento, with a virtual journey from Vela (Italy) to Kangole (Uganda), requiring more than 8000 Km travelled in a sustainable way by the children (Figure 2). The game was appreciated by teachers, children and their families. Eventually, the 87 children involved took more than 4400 home-school trips and field trips organised by the school, of which only 31 were by car, in 3 months succeeded in (virtually) travelling 8538 Km. A questionnaire-based assessment with families of the children showed that the game had a positive influence on the home-school mobility habits for 68% of the children and the effects are still observable six months after the game end.

2 GAMIFICATION AND SUSTAINABLE BEHAVIOUR

Gamification has shown its potential as a strategic socio-technical element to increase participation and engagement, and promote sustainable behaviours, such as ethical, social, environmentally-friendly, or healthy habit [3]. Serious games, persuasive games as well as gamified interactions, have proven to be useful tools not only for raising awareness about a topic or an issue but also to promote attitude or behaviour change. The key idea is to increase the motivation of people to make certain decisions, or carry out certain tasks that are instrumental in order to reach valuable objectives, by turning them into fun and rewarding experiences. Environmental sustainability is an application area where gamification approaches have been widely applied, ranging from energy savings [8, 25, 26], sustainable mobility [9, 14, 19, 20] and other environmental issues, such as community-wide environmental missions [22], participatory governance of urban neighbourhoods [5], or educational city discovery [11]. Gamification for environmental awareness and sustainability has proven successful in several of those cases; however, its impact is often transient and tends to diminish with time [11], unless it is reinforced with opportune motivational affordances [28], and corresponding game design elements and mechanics [21].

The recognition of the role of education as a key enabler for sustainable development has been growing steadily, which has led to its prominence in the 2030 Agenda for Sustainable Development and the Paris Climate Change Agreement. However, despite the considerable effort and relevant steps made in recent years (with many frameworks, programmes, and policies put in place at the international and national level), schools and local authorities alike encounter hurdles towards a systematic adoption and implementation of environmental education [19]. Gamification can hence play a key, three-fold role in this context: supporting the sustainability of environmental education initiatives in the long-term, promoting community engagement at large, and fostering creativity and active participation. There are already some successful examples that leverage gamification to promote children’s, and parents, healthy and sustainable life-styles [10, 15, 17]. However, there are still few examples of gamification approaches that specifically target children’s environmental education, like we do with Kids-Go-Green. ECOMobile for instance, implements a situated learning approach for ecosystem science learning, which can be leveraged to organise augmented playful children field trips to local pond environments [18]. Its combination of an augmented reality gamified experience with environmental probeware has proven to be very effective for children’s understanding and interpretation of water quality measurements. Beat the Street [12] is an application similar to Kids-Go-Green in its objectives, since it also aims at involving a local community of people within a competition that encourages them to walk or cycle in their neighbourhood, using tracking technology and a reward scheme. This game has been applied also in schools to promote children’s sustainable and active mobility, but preliminary studies show that the induced change was very limited [7]. This might be due to the fact that Beat the Street - as opposed to Kids-Go-Green - was not designed to specifically target children, nor to be integrated within the school setting and its didactic programme. The game mechanics, rewards and user experience in Beat the Street are designed to engage a generic player population, while those of Kids-Go-Green are geared specifically to be significant as well as attractive for young children in an educational setting, like the school, that can amplify the message.

3 THE KIDS-GO-GREEN APPLICATION

Education is unanimously recognized as crucial for the achievement of sustainable development, since it empowers individuals with the knowledge, skills, values and attitudes that transform them into change agents [27]. Education for Sustainable Development (ESD) from an early age is particularly important: it is in childhood that the foundations of many fundamental attitudes and values are established; thus, the earlier ESD ideas are introduced, the greater their impact and influence can be [4]. Kids-Go-Green has been designed to be used in a school setting for supporting active
3.1 User target, objectives and design rationales

The main objective is to induce a short term commitment towards more active and sustainable mobility habits - specifically for what concerns the home-school journey - that eventually leads to a long term attitude. In this respect, the principal users in Kids-Go-Green are children from elementary school (age group 6-11). Our game concepts, interaction mechanics and corresponding user interfaces were designed for a playful experience that is appropriate to that age group. The second objective is to locate the game in the context of the school activities. It is therefore important that the content presented is not just engaging but also has an educational value. In this respect, teachers are important users and not just stakeholders for the game. The overall design of Kids-Go-Green followed these design rationales:

**Design rationale #1.** The game metaphors need to be easily graspable by primary school children therefore we decided not to rely on traditional, more formal, concepts and measures of sustainable mobility such as carbon emissions, fuel costs, and energy saving but to deliver the message that "every step counts", that is, small individual actions can accumulate, and ultimately lead to huge impacts.

**Design rationale #2.** The game, although not educational per se (that is, not designed to support classroom teaching, or the achievement of a specific learning outcome), should always present sound content which can be easily incorporated in the syllabus and in the practices of the school. Eventually, Kids-Go-Green should easily integrate in the e-teaching infrastructure of the school.

**Design rationale #3.** Teachers’ knowledge and competencies are essential for communicating the value of sustainability in a school setting, therefore their active involvement is a key condition to the successful adoption and implementation of an ESD action [27]. Kids-Go-Green aims at an active participation of the school community at large by enabling teachers in the customization of the content and management of the game in a way that respect each teacher and each school established practices. Furthermore, the project should also aim at supporting grouping and collaboration between teachers to exchange experiences and lesson learned.

**Design rationale #4.** Last but not least, although parents and other family members are not directly involved in the game, our aim is to leverage kids’ engagement to reach their parents and siblings and induce a change in their attitude and habits. This allows to establish an amplification loop, with respect to mobility habits, that ensures longer-term effects, and wider social and community reach.
3.2 Design concept and game mechanisms

Kids-Go-Green aims at achieving the design objectives by along the rationale described in the previous section by mean of a gamified collaborative educational experience. As mentioned in the introduction, the core part of Kids-Go-Green is a virtual journey that the children has to travel by using sustainable kilometres that they travel for real in their home-school commuting.

Creating the virtual educational journey: Before the actual starting of the game, the virtual journey is created by the teachers (possibly involving the children too). The journey includes a final destination and a set of intermediate stops that are locations in the real-world. The journey can be defined according to the interests and the educational needs of the teachers in the specific context. Furthermore its length has to be calibrated to the specific situation (number of children, extension of the school district, and so on) in order to make the destination reachable within the planned duration of the game. Then, teachers can associate multimedia educational material (such as, video, pictures, web-links) to each stop. That educational material can be customised to the needs of a specific class/grade; for example, for the same stop, children in different grades can experience different multimedia contents, depending on their grade subjects and syllabuses.

Mapping real and virtual distances. Every day each class accesses the Kids-Go-Green Web application and fill in the Mobility Journal (see Figure 3): the children indicate the way they reached school on that day simply and quickly. The colour code that denotes the different transport modes is the same used by local schools during the zero emissions day, an annual event that encourage parents to substitute their car journeys to school with walking or cycling for a day. We decided to keep these colours to be consistent with a colour code already used by the children and their teachers. The amount of kilometres travelled in a sustainable way (that is, by foot, bike, walking bus, or school bus) each day by the children in their trips to school contributes to the progress on the virtual journey. The distance travelled by walking bus and by school bus corresponds in the virtual journey to the distance actually travelled by the kid, while for the other modes (car and by foot) a conventional value is used. These constant values were customised according to the average walking/cycling distance from home to the specific school. Classes may also enter walking field trips done as part of the school activities.

Game bonus and incentives. In order to cover longer distances (and make the journey more challenging) bonuses are given to the school in various situations, for additional kilometres are provided whenever children walk or cycle to school despite bad weather conditions (such as rain, snow). Furthermore, Kids-Go-Green also includes class-level and school-level challenges: upon completion of a specific objective (e.g., zero emissions day, no-car week, etc.) the school benefits from virtual prizes that can be exploited in the journey to add additional kilometres (for example, a cruise ticket along a river, or a plane ticket to reach an oversea stop).
Collaborative feedback. The progress on the journey is shown in the Kids-Go-Green Interactive Digital Map (see Figure 2), preferably displayed on a large display or on an interactive whiteboard where children can explore the path travelled so far, the school current position, and the stops already reached. Every time a stop is reached, the teachers can use the associated multimedia educational material for in-class lessons. Future stops on the school virtual journey are instead greyed out, and inactive, so that they cannot be prematurely discovered, but they are still visible and excite the curiosity of the children. The Mobility Statistics Web page allows to inspect the amount of sustainable distance performed per mode (Figure 4). Distances are shown as ideograms, where each “foot” symbol represents 10 sustainable kilometres. The statistics page thus constitutes an additional educational support, providing interactions, calculations and discussions on data which can take place at different levels for the different grades.

3.3 Enabling Technologies

Kids-Go-Green has been developed as a web app that can be accessed from any Web browser and that can be used in school by means of large display, interactive whiteboards, smart tablets or standard computers (Figure 1). Kids-Go-Green exploits an Open-source Gamification Framework [19] that enables the definition of gamification scenarios on top of existing services/apps. The Gamification Framework has been designed and developed having in mind the following principles: i) open-ended integration of existing IT systems and services in a Smart City, whose interactions with citizens must become part of the game as player actions; ii) support for dynamic game objectives, as well as a set of extensible game design elements; iii) sustaining of behavioural changes through long-running games and proper game mechanics, which can keep players engaged in the long term. The framework covers the entire game life-cycle (that is, design, deployment, execution and analysis of games) and supports a variety of extensible game concepts (such as individual and team challenges), which allow to build multi-player games with a personalized game experience either collaborative or competitive [21]. The Gamification framework has been released in GitHub under the Apache License Version 2.0 and is available as a stand-alone application as well as software-as-a-service (SaaS). It has been deployed and experimented with in a variety of Smart City games around Europe [20, 21]. For Kids-Go-Green, it has been extended to support new game concepts and incentives that are specific to the themes of children’s sustainable and active mobility.

4 FIELD TRIAL

An evaluation of Kids-Go-Green took place in the primary school of Vela, a district of the city of Trento, Italy. In the following, we start by presenting some information about the study context. We then present Kids-Go-Green evaluation results considering three main dimensions: i) participation and engagement in the game; ii) game
impact in terms of change in mobility habits; and iii) educational value and didactic opportunities.

4.1 Study Context and Settings

The field trial of Kids-Go-Green had the objective of testing whether this gamified educational experience may sustain the participation of teachers and children over time and ultimately if it is effective in changing the children mobility behaviour of children and their families toward more sustainable means of transportation.

The study involved the entire school, for a total of 87 kids, and 6 teachers. The virtual journey chosen by the school was ambitious and symbolic: from Trento to Kangole, where the school community has a long-lasting solidarity project with a local primary school. During Fall 2016, the teachers met with the researchers to define the journey path, planned the different stops (21 in total, of which 13 in Italy and the others in Greece, Egypt, Sudan, South Sudan and Uganda) and associated multi-media material to each stop. The game, involved the whole school and took place from February 24th to May 18th 2017, when the school reached the final destination. Teachers and students used the game on a daily basis for a total of 50 school days.

The data collected for the evaluation included: the Kids-Go-Green game logs, a questionnaire and depth-interviews with teachers as well as two questionnaires for the families. The game logs included daily information on the transport mode for each child obtained through the Mobility Journal, field and school trips reported by teachers through the Web application, daily kilometres per mode calculated by the Gamification Framework.

The teachers’ questionnaire aimed at assessing the educational value of the game and its sustainability in terms of effort required for the set-up and execution; it also asked about ease of integration within the class didactic programme. Individual interviews were conducted with the three teachers who were more involved in the setting-up of the game in order to gather further feedbacks and comments.

The families’ questionnaires aimed at evaluating the involvement of parents in the initiative and their perceived impact with respect to mobility habits. A follow-up questionnaire was sent to the families after 6 months to assess the effect of the intervention for what concerns the mobility habits. Both questionnaires were distributed to the families by the school admin offices. Sixty-five (65) families filled and returned the first questionnaire and 55 the second one.

4.2 Results

We start our analysis presenting demographic information about the children participating to the game (see Table 1). Since the whole school was involved, we have a relatively diverse children population in terms of gender and age. An interesting information, that will be further exploited during our evaluation, consists of the distance from home to school: most kids live less than one Km, while 11% (9/87) of the kids live more than 3 Km far from school.

During the 12 weeks of game, the children covered a distance of 8538 sustainable Km, of which 3332 Km where done on foot or by bike, 1714 Km by school bus, and the rest was bonus distances gained through the achievement of class or school challenges (Figure 5). Some of these challenges required the collaboration of players to achieve a day with no car trips for the whole class. Twenty four (24) days over 50 have been days occurred without any car trips (48%). Over a total of 4409 home-school trips, only 31 were taken by car (less than 1%), 3426 trips were taken on foot or by bike and 952 by school bus (Figure 6). Other bonuses were given when students walked to school during raining days or when the entire school participated in special events, like the zero emission day.

In a follow up questionnaire at 6 months from the end of the initiative, 89% of the respondents (52/55) reported that they use the same modality from the last year, with the most frequent travel modality being the walking bus, followed by the school bus, independent walking and, lastly, the car.

4.2.1 Impact on children and teachers engagement. Concerning players’ participation and engagement, children filled the Mobility Journal on a daily basis throughout the game, for a total of 4409 recorded trips over 50 school days (the count includes home-school trips and field trips alike). Teachers’ involvement was fundamental to achieve this result. It is worth mentioning that even after reaching their final destination, the school continued playing the game and reporting daily trips till the end of the school year. From questionnaire responses, it appears that all teachers are willing to repeat the game in the next school year. Since we were interested in leveraging on children’s participation as a means to reach out to

<table>
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<tr>
<th>Table 1: Student population (N= 87)</th>
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<tr>
<td>Gender</td>
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Figure 5: Virtual distance distribution
4.2.2 Impact on families’ mobility habits. Looking at the impact on children’s mobility habits, we asked parents whether the game influenced the habits of their child(ren) (Figure 7). For the 42% (27/65) of the respondents Kids-Go-Green had a positive impact on the way children reached school and for the 26% (17/65) the game changed their mobility habits also during free-time and family trips. The remaining perceived no (12%, 8/65) or little (20%, 13/65) improvement. A further analysis revealed that those who gave lower scores live less than 1 kilometre from school (Figure 8), and were already using sustainable travel modes such as walking or the walking bus service (which is the home-to-school transport option most in line with sustainability and independent children mobility principles).

4.2.3 Educational value and didactic opportunities. In terms of the perceived educational value of the Kids-Go-Green game, the feedback from teachers and children was generally positive. The most used features were the mobility journal and the interactive map, while the statistics and the challenge sections were less frequently used during class (Figure 9). Kids-Go-Green was used as an engaging approach to introduce new topics in class. In creating the journey, the teachers reported that they mainly used multimedia material from online sources to provide the content, such as videos, images, photos, extracts from movies. Furthermore, the multimedia material was combined with practical activities and group works (e.g. conduct small scientific experiments or art projects) to enrich the lessons and promote children participation. A teacher reported: “It was a very rewarding experience […] The children were learning while playing”.

For what concerns the children engagement, teachers reported that all students were very motivated in using the game throughout the whole period and that children themselves reminded the teachers of turning on the application. A teacher said: “When I entered the class in the morning I did not have to remember to turn it [Kids-Go-Green] on, the children remind me to start the computer!”.

Concerning the sustainability of the game, in terms of effort required for the game set-up, it was considered totally feasible for four teachers and quite feasible for the remaining two (from the questionnaires). From the interviews, teachers reported that the main issues were technological (specifically, issues with the internet connection and the computer set-up) but they also recognised that those issues could be resolved through practice. The multimedia resources were used for several subjects such as geography, language, history, mathematics, natural science and civic education. According to the teachers, the children’s appreciated the fact that the game enables a playful approach to traditional school subjects. Moreover, the game encouraged students’ curiosity and willingness to actually visit the places they explored only virtually. This aspect was also explicitly reported by thirteen parents in the open questions in the questionnaire.

A teacher pointed out also the multicultural value of the game “"The activity encouraged the children to know more about different places and different cultures […] When we reached certain stops children with an immigrant background presented their habits or translated some text to the class". While the students proceeded in
their journey, the teacher could introduce to the class different topics related to multicultural and diversity education, supported by the multimedia resources. This value the participation of students with an foreign background to the class activity by sharing their experiences and to be even more involved in the learning process. The game has indeed the potential to support inclusive education practices combining geography with the multicultural dimension, and providing opportunities for the class to learn different cultural patterns and identities.

An interesting effect of the game concerns the fact that it promoted collaboration and team-building within the school, as illustrated by this comment from one of the teachers: "Kids-Go-Green nurtured team-building and sense of belonging both within the classes and across the whole school". At the class level, classmates teamed up to advance in the journey map. As future improvements, teachers suggested to have a shared representation of the journey map displayed in a common space in the school, such as in a big screen in the main hall, in order to make the entire school always aware of the journey common progress.

Yet, the teachers also highlighted some limitations of the system. First of all, they would have appreciated more advanced features such as the ability of sharing the teaching ideas and materials within the application in order to create a common repository and help lesson planning. They expressed the need for a better control over the journey, for example the possibility of adapting the journey and the stops to different classes (for example using different stops depending on the students' age) in order to better fit the game dynamics with other activities in the school. Finally, they would also have appreciated a way for informing the parents on the progress on the journey and for directly involve them in the game activity.

5 DISCUSSION

This trial of Kids-Go-Green has contributed to the understanding of the effect of this type of game-based learning interfaces for improving sustainable behaviour. The main lessons that we have learnt through this experience can be summarised as follows. Keeping the school united, working towards a common goal and reaching common achievements were all important aspects supported by the use of the Kids-Go-Green application. Providing a shared interfaces in the class has proven to facilitate the integration of new media in the other educational activities conducted in the school. The children were able to follow their progress on a daily basis, having a tangible feedback of their shared contribution along the virtual journey.

More importantly, their contribution was reflected also on the transport modality adopted in their daily commutes to school. The follow up questionnaire showed that this behaviour can be maintained after the game activity ends. The whole student population positively responded to the challenges that were set during the intervention, adopting sustainable modalities for reaching the school. The parents' responses highlight that sustainable behaviour was also generalised to other contexts, such as leisure time and family travels, at least for some of the pupils.

According to the teachers, the intervention brought also some curricular benefits. Teachers were able to use of digital resources provided by the application for introducing and supporting class activities, while children showed a stronger engagement during the lessons. The educational material has indeed provided added value in the practice. Since the evaluation presented here was focused on the effect on sustainable behaviour, the educational value of this approach will be further evaluated in future studies.

Future studies are also needed to determine whether our findings can be generalised to a broader population. Participants involved in this study are from a suburban community, and the streets close to the school were generally safe and fit for walking. Different outcomes might expected when considering other populations, such as urban areas or locations with different traffic and street safety conditions.

6 CONCLUSIONS

Children are the citizens of the future, and thus education and the feeling of being part of a community plays a fundamental role in shaping our future society. Walking or cycling together with other children, being part of an active community of citizens and seeing the impact on society and environment of their own choices significantly contribute to shape children’s character as a functional member of society. In this paper we described Kids-Go-Green, a playful educational experience aiming at improving children’s mobility habits through novel gamification metaphors and mechanics. Kids-Go-Green has been used for a period of 3 months in a school in Italy. The results are very promising in terms of end-user participation and engagement, impact on mobility habits and educational value.

As future work, we plan to extend Kids-Go-Green with new functionalities aiming at making teachers more autonomous in the definition and set-up of games. This will improve the sustainability and scalability of the proposed solution. Moreover, we plan to extend the game mechanics in order to promote children’s safe road habits when walking or cycling alone to school (for example, exploiting smart wearable devices to check and reward children that follow safe road paths identified by the community and the local police).

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