Hakoniwa: Enhancing Physical Gamification using Miniature Garden Elements

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Fig. 1. The Hakoniwa Prototype. In our approach, we implemented physical gamification using Japanese miniature garden elements in order to increase user motivation and persuasiveness.

Gamification has been shown to increase motivation and enhance user experience. Novel research proposes the addition of physicality to otherwise digital gamification elements for increasing their meaningfulness. In this work, we look towards gardens in the context of gamification. Motivated by their positive impact on both, physical and mental health, we investigate whether gamification elements can be represented by miniature garden elements. Based on the rules of Japanese Gardens, we contribute an exploratory framework informing the design of gamified miniature gardens. Building upon this, we realize physical implementations of a waterfall, a sand basin and a water pond reflecting the gamification elements of points and progress. In an online study ($N = 102$), we investigate the perception and persuasiveness of our prototypes and outline improvements to support further investigations.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Interface design prototyping**.

Additional Key Words and Phrases: gamification, physicality, meaningfulness, Japanese miniature gardens

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1 INTRODUCTION

Gamification, *the use of game design elements in non-game contexts* [11], has been used successfully to motivate people across various domains [14]. It has been shown to lead to an increased enjoyment of unpleasant activities, to change people's behavior and in general to enhance user experience [14, 32]. To increase its success, research proposes to emphasize the *meaningfulness* of gamification [25, 41]. Meaningfulness is defined as the value of an activity, judged in relation to an individual's own ideals [21]. In the Self-Determination Theory, a theory on human motivation [28, 29], meaning has been proposed as a basic psychological need [29], next to autonomy, relatedness and competence. Thus, enhanced meaningfulness might be beneficial for users' motivation, which is often aimed to be increased when using gamification.

We address meaningfulness in gamification by considering its *physicality*. While Deterding et al. [11] noted in their definition of gamification that it is not limited to digital applications or services, most interventions tend to use virtual game elements [14, 32]. Novel approaches have shown success by implementing gamification elements in a physical manner using 3D printing technologies [17, 26]. Moreover, tangible rewards were shown to increase user activity substantially more than intangible rewards [22] and to be advantageous over intangible rewards in motivating users over a longer time-span [13]. Additionally, outside of the gamification domain, it has been shown that physicality leads to increased enjoyment, playfulness and realism [43]. Building upon these insights, we aim to counter common criticisms of gamification, such as *pointsification* [25] or *exploitationware* [4].

To create more relatable and enjoyable physical representations of gamification elements, we look towards nature, and more specifically to Japanese miniature garden elements. From a general perspective, green environments positively influence visitors' psychological and physiological state [33, 40]. Additionally, gardens benefit humans in aspects of stress reduction [35], life satisfaction [42] and mental as well as physical health [7, 34]. Especially observing Japanese gardens has been shown to lead to deeper relaxation compared to simple landscapes [12]. In HCI, plants and other living organisms have been utilized to create so called Living Media Interfaces, i.e. *those interfaces that incorporate living organisms and biological materials into artefacts to support interaction between humans and digital systems* [23]. Past research has demonstrated that such interfaces are able to promote human empathy, enhance the meaningfulness of the interactive system and convey affect or agency [5, 23]. We utilize this approach to investigate whether digital gamification elements can be transformed into miniature Japanese garden elements. Based on a design exploration, we derive transformations from purely virtual gamification elements to potentially more meaningful, physical miniature garden elements, such as waterfalls, or sand. To investigate the perception and motivational impact of these garden elements as well as their suitability to mimic virtual gamification elements, we conceptualized and implemented three prototypes, representing the commonly used gamification elements of points and progress. Our Hakoniwa prototypes represent progress towards a goal through a pond able to fill itself with water, a waterfall able to alter its height level, and an automated basin able to draw into the contained sand. We studied our prototypes in an online study ($N = 102$), where we confronted participants with videos and pictures illustrating how the miniature garden elements represent progress.

Our contribution is two-fold. First, we contribute three technically mature prototypes for interactive miniature garden elements, which can be used to mimic the concept behind the gamification elements of points and progress. We based the design of these prototypes on a design exploration, weaving the design space of Japanese miniature gardens into gamification elements by combining common themes. The resulting design suggestions can be used to guide the concept of future garden elements in the domain of persuasive technology or gamification. Secondly, we provide insights from an online study investigating the perception of our three prototypes in several domains relevant to persuasive or gameful applications. Based on these insights, we shed light on the perceived persuasiveness of our prototypes, the suitability of such interactive miniature gardens for ambient displays of gameful design elements, the effect of the application domain and user preferences in general. Lastly, we conclude by deriving concrete design implications based on our findings.

2 RELATED WORK

In the following section, we provide an overview of work related to our investigation. We frame the challenges within the field of gamification, outline existing approaches for combining gamification and gardens to increase user motivation, and describe how HCI has considered living media as ambient displays.

2.1 Gamification

The positive effects of gamification have been shown to hold true in various domains, including education, health, crowdsourcing or commerce [14]. As the field of research in gameful systems keeps expanding, it has also proven to successfully make the leap into the industry [24]. While the growing amount of studies keep underlining the benefits of gamification in terms of user motivation, neutral or negative results are often accredited to the selected participants or the implemented gamified system. It is for these reasons that suggestions have been made to take user specific aspects into account when designing gamified systems.

By comparing multiple studies in the field of gamification, Toda et al. [39] take a deeper look into the downsides and negative effects of gamification. Authors identify issues arising in gameful systems, such as loss of performance, undesired behavior, indifference and declining effects. They attribute these negative effects to the gamified design and found them especially in occurrence with the leaderboard game element. Recently, research has started investigating novel approaches to counter the downwards trend. One such example implements gamification in a physical manner through 3D printing artefacts, such as caterpillars and butterflies [26]. Based on individual performance, a user receives a differently sized caterpillar in regular intervals, to a point where the caterpillar transforms into a butterfly. Due to the physicality, this approach aims to increase user engagement and encourage users to develop their own meaning towards the object. Similarly, Khot et al. [17] used physical 3D prints to visualize users' physical activity. Out of several variants, participants were most affected by a frog increasing in size in relationship to their activity levels. These insights are further supported by Meder et al. [22], who found an increase in user activity when rewarding users with physical instead of virtual rewards.

Given that gamification has recently received valid criticism in terms of meaningfulness, or *pointsification* [25], novel techniques, such as physicalization, might be able to counteract potential desensitization and open up new methods for gamified design. In this work, we build on this idea by considering physical garden representations of gamification elements.

2.2 Gardens and Gamification

Gardening has been a substantial part of humankind for a very long time. One of the longest known gardening techniques is Japanese gardening. Presumably the oldest record documenting the art of Japanese gardening is the *Sakuteiki* [37] (Records of Garden Making) written over 1000 years ago.

Research investigating the psychological effects of gardens and gardening underline various benefits, such as a reductions in stress levels [35], increased life satisfaction [42], and increased mental as well as physical health [7, 34]. Compared to conventional landscaped gardens, observing Japanese gardens decreases the viewer's heart rate [12]. Such positive effects could be used to counteract negative effects of gamification such as psychological stress.

To the best of our knowledge, not much research has been done in regard to gardens as gamified persuasive elements. One work by Holstius et al. [15] investigates a plant-like prototype encouraging increased recycling behavior. A plant situated between two light sources and two bins leans into the direction where more trash is thrown, as each time the bin is used, the light on the respective side starts to shine. Their evaluation indicates an increase in recycling behavior, hinting towards a positive effect of using such playful, physical and natural media for persuasive tasks. Similarly, Consolvo et al. presented the *UbiFit Garden* [8], a digital gamified garden, where recorded activity results in the representation of growing flowers and butterflies appearing throughout the week on a mobile phone's wallpaper. Feedback from participants suggests a persuasive effect on user motivation raising the question to what extent a physical gamified counterpart could influence user behavior. We build upon this notion and consider the positive effects of Japanese gardens as ideal subjects for physical and persuasive gamification.

2.3 Living media as ambient displays

While research on garden elements as ambient displays is rather sparse, many works contribute to so called *living media* ranging from simple information displays [5, 30] to display-enhancing artificial plants [9, 10]. One of the early examples is Cheok et al.'s *living empathic media* [5]: glowing E. coli bacteria displaying information with a brighter or dimmer glow and different colors. Their users were not only highly receptive of the prototype, but also preferred it over its digital counterpart. Hong et al. [16] built a flower-shaped ambient avatar to display a user's posture by bending its stem and changing its color. Furthermore, cabbage has been used to display heart health [30] and Chien et al. [6] successfully showed that plant growth and FitBit data could be linked and understood by observers. Usually these kinds of prototypes come with the disadvantage of slow adaption as plants need time to grow, or in case of the cabbage, change color. On the other hand, gamified garden elements should be able to adapt and react comparatively fast, shifting the focus away from living media in a garden towards using natural media as ambient displays, hence, focusing more on static, non-living elements within a garden that can be adapted more quickly.

2.4 Summary

Related work has shown that adding a physical dimension to gamification could be a new approach for gamified designs by representing known elements such as points or leaderboards behind physical, ambient displays. Combined with the positive influence of gardens on physical and mental health [7, 34, 35, 42], garden elements used in traditional gardening techniques such as Japanese gardening show potential to benefit such an approach and counteract the negative side effects of gamification some users experience [14, 39]. As research towards living media has shown, it is able to convey information as an ambient display [6, 30], but usually lacks the ability to adapt quickly making it unfavorable to use in a gamified context. Therefore, non-living garden elements could take over this task and function as gamified displays.

In this work, we take a first step into using garden elements as gamification displays to expand on the common digital approach. We start by focusing on building physical garden representations of gamification elements through a design exploration. By studying our Hakoniwa prototype in an online survey, we derive design implications for future research towards gamified Japanese gardens.

3 DESIGNING GAMIFICATION WITH MINIATURE GARDENS

In the following section, we elaborate on our exploration of miniature gardens and their potential to serve as physical representations of gamification elements.

3.1 Gamification Elements

To gain an understanding of representing gamification elements in the form of miniature garden elements, we started by defining a set of applicable gamification elements frequently used in literature [14, 32]. We decided on the elements of Points, Progress Bars, Badges and Unlockables.

As the most commonly used gamification element, *Points*, creates an understanding of one's progress using numerical representations [14, 32]. Points usually are used to indicate progress on the micro-level, i.e. by using numerical units [32]. Building on this, a *Progress Bar* represents the progression as a percentage of a certain goal. In contrast to Points, this element indicates progress on the macro-level. Often, Progress Bars are used on top of Points, visualizing the number of points in relation to a milestone or higher-level goal [32]. Upon reaching certain goals, *Badges and Unlockables* visually represent achievements made, e.g., by granting trophies or awards [32]. In contrast to Points and Progress Bars, Badges and Unlockables represent the achievements of goals instead of progress towards them and thus can be seen as rather static elements.

3.2 Japanese Garden Elements

As a physical representation of gamification elements, we decided to focus on Japanese Miniature Gardens [20]. Traditional Japanese gardens are known for their structured and aesthetic design [1, 37]. We specifically focused on this approach as the structured rules of Japanese garden design provide an ideal framework to start from. While different types of Japanese gardens exist, their two main principles are scaled reduction and symbolism [27]. As an example, Zen Gardens create miniature stylized landscapes which serve as an aid for meditation and awareness. With the latter, we drew the connection to how gamification builds self-reflection, i.e., by bringing insight into one's progress and performance.

Japanese gardens consist of different elements, i.e., Water, Architecture, Fauna and Flora, and Natural elements. Water elements are an essential base of the composition of a Japanese garden and symbolize the continuous flow of time and life changes. Traditional examples of this element include ponds, streams, waterfalls and springs. In "dry landscape" gardens, water is represented by gravel and sand which visually flows through rocks [2]. As an essential representation of the path through life, architecture elements guide guests through a variety of garden experiences and perceptions. They are made of natural materials and can be found as pathways, bridges, benches, stone lanterns, wells, fences, and gates. Animals and plants bring decorative aspects to a garden and provide symbolic meaning. Plants bring together separate parts of the garden, soften the lines and create the background. Lastly, natural elements such as stones provide framing to a garden and symbolize permanence and immutability.

3.3 Design Exploration

In our design exploration, we connected the different elements of a Japanese garden to our gamification concepts. In this section, we detail on the design patterns that occurred and derive concrete design suggestions. While our suggestions are not exhaustive and can be interpreted differently, they aim to connect both concepts in a consistent manner.

Points and Progress transform Water. Points and Progress Bars have a highly dynamic nature due to their direct feedback provided to the user. To reflect fluent changes, *Water* is a particularly suitable element approach. Being an essential base of the composition of Japanese gardens, Water bears similarity to Points which are considered to be the smallest unit of progression feedback, and to Progress Bars which provide a visual understanding of the distance to an upcoming milestone. Additionally, the fact that Water elements symbolize continuous flow aligns well to the dynamic nature of Points and Progress Bars when representing progression towards goals. Examples of this pattern are ponds that change their water level based on progress, or a river that flows stronger. Here, we derive the first design suggestion **DS1: Points and Progress Bars could be represented using *Water* elements of a Japanese Garden**.

Progress Bars opens up Architecture. Progress Bars are used to visualize the progress towards goals within gameful applications. While they have a similar nature to Points, their aim is not to provide atomic progress, but rather a visual understanding of the distance to an upcoming milestone. This interpretation bears similarity to the *Architecture* within a Japanese garden. Paths in Japanese culture symbolize the path through life, escorting the garden guests through a variety of garden experiences and perceptions. They are like little streams that weave through the entire depth of the garden. On this path of progression, there could be a tea house that opens up when reached, or a lantern lighting the way. To make this connection, we derive **DS2: *Architecture* elements such as pathways could be used to represent progress towards goals, similar to Progress Bars**.

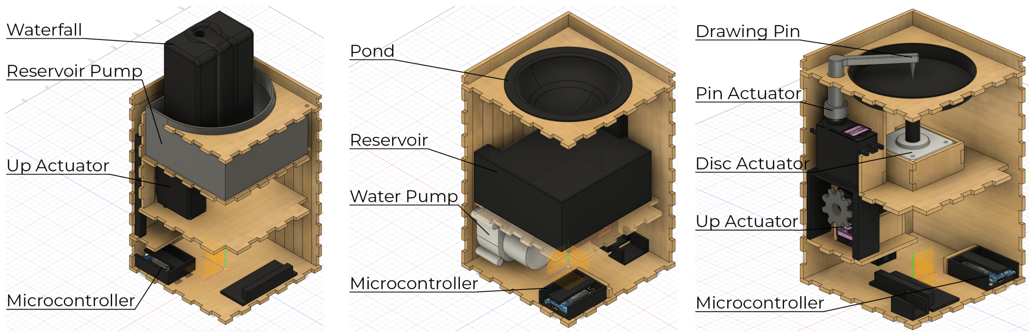
Badges and Unlockables activate Nature and Fauna/Flora. In contrast to representing progress, Badges and Unlockables represent the achievement of certain goals, and are static portrayals of the current state. In the context of Japanese miniature gardens, both Fauna/Flora and Natural elements are bound to the impression of the current season, and have a symbolic meaning connected to permanence. Examples of Badges and Unlockables inside a Japanese garden could be a bonsai blooming, or Koi fish appearing in a pond. Thus, **DS3: Badges and Unlockables could be represented using *Nature* elements or *Fauna/Flora* elements**.

4 HAKONIWA PROTOTYPE

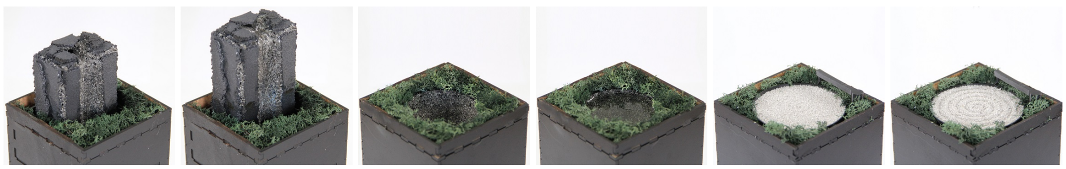
To study our concept of gamified Japanese Miniature gardens, we created three prototypes called Hakoniwa, the Japanese word for a boxed or a miniature garden. We decided to focus on the combination of the gamification elements of Points and Progress and the Japanese garden element of Water. Based on our design exploration, we implemented prototypes in the form of a waterfall, a pond and a sand basin. While the latter does not incorporate real water, it follows the notion of a "dry garden".

Each element consists of a $10 \times 10 \times 15$ cm MDF box to contain the hardware, and Wemos D1 Mini microcontrollers drive all electronic parts. For aesthetic purposes, a combination of sand, imitation stone and moss decorates the elements. The elements and their internal sketches are depicted in Figure 2.

Waterfall. The first element consists of a waterfall that is able to alter its height, depicted in Figure 2d and 2e. This change in height influences the flow and visibility of the running water, representing a different amount of points or



(a) Waterfall Technical Sketch (b) Pond Technical Sketch (c) Sand Technical Sketch



(d) Waterfall Low (e) Waterfall High (f) Pond Empty (g) Pond Full (h) Sand Clean (i) Sand Spiral

Fig. 2. The technical representation of the Hakoniwa prototypes. Figures 2a, 2b and 2c show the 3D model cutout of each prototype. Figures 2d through 2i depict the minimum and maximum states of the waterfall, pond and sand basin elements respectively.

progress level. The element uses a one-way water pump controlled by a relay, and two servo motors functioning as actuators lifting or lowering the waterfall as needed, see Figure 2a. The shape of the waterfall, as well as the water reservoir are both 3D printed, with the reservoir being hidden inside the wooden box.

Pond. To indicate a different amount of points or progress level, the pond prototype is able to change the level of visible water, see Figure 2f and 2g. Similar to the waterfall, it has a 3D-printed water reservoir as well as a 3D printed pond surface. Water is transferred from the reservoir into the pond and back using a bi-directional peristaltic pump, see Figure 2b.

Sand Basin. Lastly, the sand basin operates similar to a record player and represents points or progress using markings in the sand, see 2h and 2i. The sand itself is placed within a 3D printed basin on top of a stepper motor, which allows the basin to rotate endlessly, see Figure 2c. During rotation, a pin attached to an arm sitting on two servo motors draws into the sand. While one servo controls the angle of the arm, the second is able to lower the pin into the sand.

5 ONLINE STUDY

In the following section, we elaborate on the study design used to evaluate our Hakoniwa prototypes.

5.1 Design

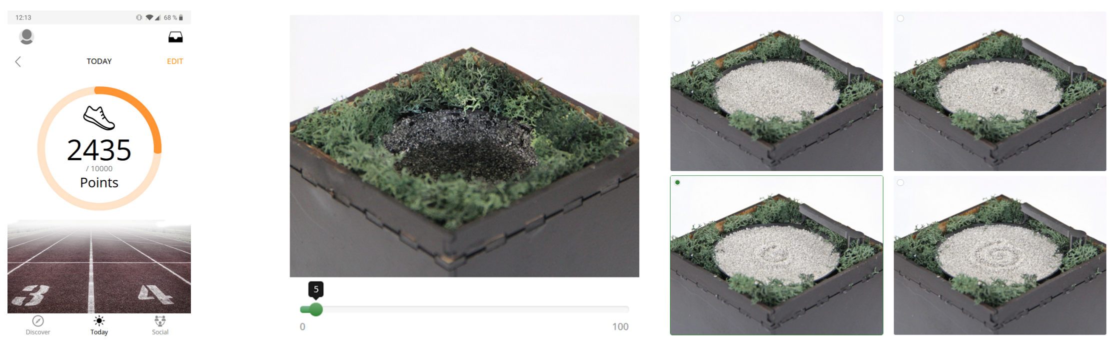
We aimed to gain insights into the potential of using miniature Japanese garden elements in conveying concepts known from the field of gamification, and to determine the capacity of our garden elements to function as ambient displays. Due to the ongoing COVID-19 pandemic, we reverted our investigation to an online study design using images and videos of the prototypes. This approach does not take full advantage of the physicality of our prototypes, however does serve as an initial validation. Our study was designed with the following research questions in mind:

- **RQ1**: Do the garden elements yield potential to persuade users to change their behavior?
- **RQ2**: How does their perceived persuasiveness compare to existing approaches like digital gamification?
- **RQ3**: Can users read and understand the element as an ambient display?
- **RQ4**: How would users use the elements to display progress towards goals?
- **RQ5**: Are different elements preferred in different gamification-related contexts?
- **RQ6**: When would users like to be rewarded by an element?
- **RQ7**: Do users prefer a gamified Japanese garden over a common gamification approach?

5.2 Apparatus

To study the prototypes in an online environment, we took pictures of each element progressing from its initial state to its final state in six steps. Each element's progress was captured indicating 0%, 17%, 33%, 50%, 67%, 83% and 100% levels of progression. Additionally, we recorded a video for each prototype showcasing its transformation from start to finish. Figures 2d through 2i illustrate the start and finish states for the waterfall, pond and sand basin elements respectively. For consistency, each recording was shot from the same angle with fixed lighting conditions and camera settings.

5.3 Procedure



(a) Mockup of a gamified application. (b) Section of the reading task. (c) Section of the choices in the assign task.

Fig. 3. Sections of the online study. Figure 3a shows the mockup of a digital gamified sports application motivating running. Figure 3b depicts an example of the reading task, where the slider below the image could be used to indicate the fullness of the pond. Lastly, 3c shows four out of seven possible answers to indicate progress towards a weekly goal.

The survey consisted of six parts: An assessment of *familiarity with gamification* in different contexts, *perceived persuasiveness*, *readability*, the *prototypes as progression displays*, *contexts* and, lastly, *demographic data*.

For the assessment of *familiarity with gamification*, we chose three contexts present in Hamari et al.'s [14] literature review and Seaborn & Fels' [32] survey on gamification research. These were health (referred to as sports due to the framing of some questions later on), education and productivity. For each context we provided a prominent example (Runtastic, Duolingo, and Do It Now) and asked about their familiarity with the context on a five-point scale (1 meaning *never heard of it*, 5 meaning *use it regularly*). Additionally, each participant could enter up to three further gamified contexts that they know of and answer on the scale accordingly.

For the *perceived persuasiveness* part, we used the perceived persuasiveness questionnaire from Thomas et al. [38]. With its three subscales we gain insights into perceived *effectiveness*, *quality* and *capability* of our prototypes as well as perceived persuasiveness in general, as a combination of every factor. Questions in each subscale are answered on a 7-point likert scale from "strongly disagree" to "strongly agree". In addition, we created a mockup of a digital gamified running app (see Figure 3a) and assess the perceived persuasiveness of this prototype as well. This way, we gain an understanding of our approach in comparison to an existing gamification approach and investigate **RQ1** and **RQ2**. Each prototype and each question appeared in randomized order.

The *readability* part tries to asses how each prototype displays certain values for users since the elements function as ambient displays. It is hence important to know how users read them (**RQ3**). Therefore, we showed an image of an element in a certain state of progression and asked participants to rate on a scale from 0 to 100 how far the element has progressed in that depiction. For example, questions inquired how full the pond is on the image shown, how big the sand spiral is or how high the waterfall has elevated. This is exemplary shown in Figure 3b. To prevent learning effects, the images and elements were shown in randomized order. In order to give them a better perception of the elements each question group for an element started with a video showcasing its transformation from beginning to end.

Next in the *prototypes as progression displays* part, our goal was to understand how users would use the prototypes to display progress towards a certain task (**RQ4**). Therefore, we presented a scenario to our participants (e.g. "Today you completed 15% of your weekly running goal") and let them choose from a pool of images of one garden element in different states, which one they think represents the described progress best. Figure 3c shows four out of seven possible answers to such a question in terms of the sand basin prototype. This was repeated for multiple degrees of progress (15%, 50%, 85%, 100%) and additionally for 115% progress to see how they would use the limited range of the garden elements to display over-achievement. Again, each element and each degree of progress appeared in randomized order.

The *contexts* part aims at answering **RQ5** and **RQ6**. Here, we tried to find out whether different contexts have an influence on the choice of garden elements and when the element should display its change to reflect progress. Therefore, users were asked to order the garden elements from most favorite to least favorite in the contexts of sports, education and productivity. Afterwards they answered the question "When would you like to see the change in the element take place?", which they could respond to with "During the task", "After finishing the task" or "Triggered by myself". Additionally, we asked those questions on a neutral basis, free from any context. Afterwards, to answer **RQ7**, participants were offered a choice between the digital prototype and a gamified garden consisting of the prototype elements to increase motivation towards a task and were asked to pick the one they would prefer to use.

Lastly, the survey finishes with questions on *demographic data* (age, gender, nationality), as well as comments on each element and the study itself.

5.4 Participants

A total of 105 participants took part in our study, out of which 47 self-identified as male, 57 as female and 1 as diverse. Most of them were from the UK (62) and Germany (28), while other origins were American (7), Belgian (3), Kazakhstan (2), Bulgarian (1), Greek (1) and Scottish (1). Ages ranged from 18 to 60 years old, with most participants being between 25-31 years old (37), followed by 18-24 (31), 32-38 (16), 39-45 (12), 46-52 (4), 53-59 (3) and 60 or older (2). 35 Participants were recruited via mailing lists, another 70 via Prolific[1]. Participants from Prolific received £2.75 as compensation for an

[1] Prolific - https://www.prolific.co/

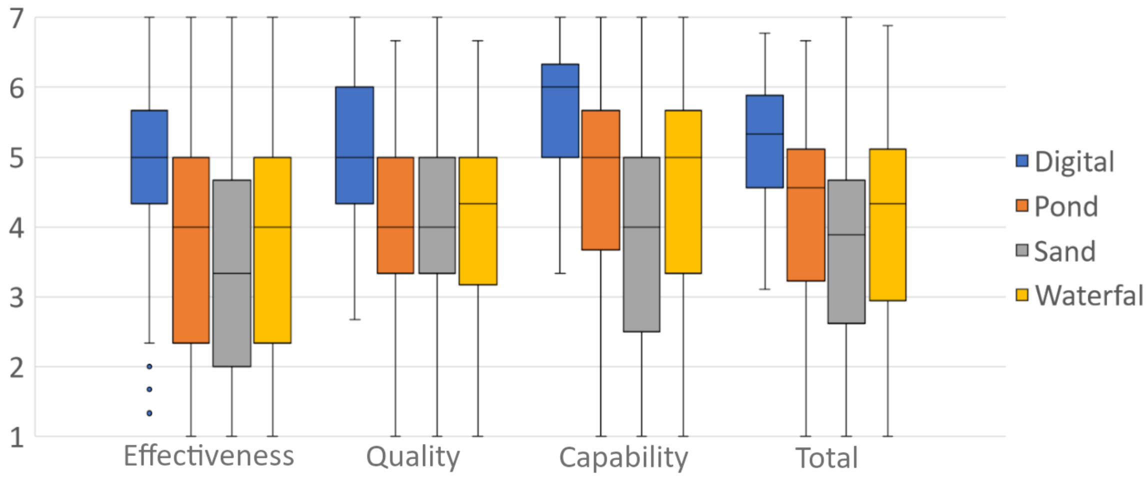


Fig. 4. Boxplots of the perceived persuasiveness subscale and total scores for each element.

estimated 22 minutes duration for the study. Three participants were excluded from our final data set due to completing the study in less than 10 minutes and answering questions randomly, leading to a total of 102 participants.

Participants rated on a scale from 1 (*never heard of it*) to 5 (*use it regularly*), how familiar they were with gamification in the context of sports ($M = 3.21$, $SD = 1.25$), education ($M = 3.14$, $SD = 1.25$) and productivity ($M = 2.52$, $SD = 1.26$). Additionally, participants mentioned to be familiar with gamification in the context of self-hydration (5 mentions) and dieting (4 mentions).

6 RESULTS

In the following section, we detail on the results from our online survey.

6.1 Perceived Persuasiveness

Regarding the perceived persuasiveness questionnaire (**RQ1** & **RQ2**), the digital mock-up application received the highest effectiveness ($M = 4.82$, $SD = 1.17$), quality ($M = 5.01$, $SD = 0.99$), capability ($M = 5.70$, $SD = 0.88$) and total score ($M = 5.18$, $SD = 0.83$). Next was the pond prototype (effectiveness, $M = 3.76$, $SD = 1.65$; quality, $M = 4.12$, $SD = 1.31$; capability, $M = 4.48$, $SD = 1.56$; total, $M = 4.12$, $SD = 1.39$), followed by the waterfall (effectiveness, $M = 3.66$, $SD = 1.66$; quality, $M = 4.04$, $SD = 1.35$; capability, $M = 4.44$, $SD = 1.60$; total, $M = 4.05$, $SD = 1.40$), and lastly the sand basin (effectiveness, $M = 3.22$, $SD = 1.53$; quality, $M = 3.96$, $SD = 1.35$; capability, $M = 3.98$, $SD = 1.61$; total, $M = 3.72$, $SD = 1.35$). Boxplots of each rating are shown in Figure 4.

To compare them to each other, we ran a repeated measures ANOVA on all subscales and total scores, adjusted using the Green-house-Geisser correction. They revealed significant differences between each tested prototype and the digital application (effectiveness, $F = 42.61$, $df = 2.44$, $\eta_p^2 = .30$, $p < .001$; quality, $F = 39.84$, $df = 2.36$, $\eta_p^2 = .28$, $p < .001$; capability, $F = 52.66$, $df = 2.18$, $\eta_p^2 = .34$, $p < .001$; total, $F = 58.70$, $df = 2.29$, $\eta_p^2 = .37$, $p < .001$). The pairwise comparisons, adjusted using the Bonferroni correction, show that the digital version's total score differs significantly from each prototype (pond, $p_{adj} < .001$; sand basin: $p_{adj} < .001$; waterfall: $p_{adj} < .001$). Within the garden elements themselves, the sand basin differs significantly from the pond ($p_{adj} = .001$) and the waterfall ($p_{adj} = .003$). Both, the

Table 1. Outcome of the readings task with our expected value (Exp) vs. the group mean in addition to the standard deviation (SD), the number of people reading a value within the range of expected value +/-10% and the number of people having all readings within the given range.

	Pond				
Exp	17	33	50	67	83
Mean	11.65	24.53	43.13	62.02	79.04
SD	13.67	11.95	16.71	16.56	15.96
#+/-10%	58	49	56	66	77
#all			24		
	Sand Basin				
Exp	17	33	50	67	83
Mean	5.02	14.86	31.09	57.58	85.86
SD	6.00	6.72	11.26	14.58	15.54
#+/-10%	18	15	26	51	61
#all			2		
	Waterfall				
Exp	17	33	50	67	83
Mean	18.30	28.63	39.81	52.42	71.09
SD	17.85	19.01	19.76	22.89	24.25
#+/-10%	38	38	40	30	36
#all			1		

pond and the waterfall on the other hand show no significant differences ($p_{adj} = 1.0$). This is analogous for the pairwise comparisons of the effectiveness and capability subscales. Solely the quality subscale deviates from this pattern as only significant differences between the digital mock-up and the garden elements were found (pond: $p_{adj} < .001$; sand basin: $p_{adj} < .001$; waterfall: $p_{adj} < .001$), but not between the pond and the sand basin ($p_{adj} = .648$), the pond and the waterfall ($p_{adj} = 1.0$) or the sand basin and the waterfall ($p_{adj} = 1.0$).

6.2 Element Readability

To get an idea on whether our participants were able to read the garden elements as ambient displays the way we intended we made a comparison between the values we expected to be read and the group average for each reading (**R31**). Those can be found in Table 1 in addition to the standard deviations, the number of people who were able to estimate the expected value +/- 10% and lastly the number of people who managed to estimate each value within the +/- 10% range for all readings. We allow a deviation of 10% due to the ambient displays not displaying plain numbers. As can be seen in the table, in almost all the pond related readings more than 50 out of 102 participants were able to estimate a value within the range. 24 submitted values where each fell within this range, i.e. estimated every depiction of the pond correctly. For the waterfall, only 30 to 40 people managed to estimate one value correctly with only one submitting all values within-range. Lastly, the least amount of people estimated the sand basin readings correctly with the first three having between 15 to 26 correct guesses and the last two having 51 and 61. Two participants were able to estimate every value within-range. The waterfall shows a noticeably higher standard deviation than the one of the the pond and the sand basin. This hints at increased difficulty to read a value from the waterfall's state.

6.3 Element Assignment

In the assign task investigating **RQ4**, participants chose an image which, in their opinion, represented a weekly goal progress of 15% / 50% / 85% / 100% and 115% best. The pool of images to choose from showed the prototypes after 0%

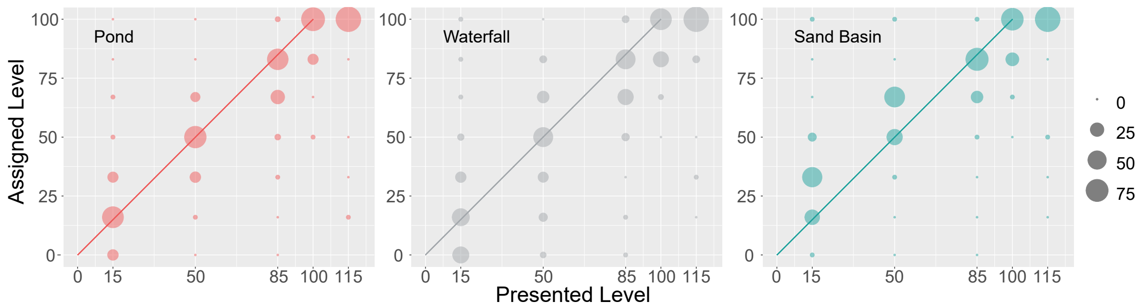


Fig. 5. Element level assignments for each garden element. Here, the X-axis represents the level that was visualized to the user, while the X-axis represents the level the user assigned to the visualization. In each graph, the size of the circles represent the amount of the indications for a given combination. The linear function depicts the 1-to1 mapping of achievement level and garden element state.

/ 17% / 33% / 50% / 67% / 83% and 100% progression. Figure 5 shows the distributions of the participants' choices for each element and for each level of progression. In most cases, the closest prototype progression was chosen for the respective weekly goal progression, as for the pond, the second image (17%) received the highest amount of votes for 15% progression, the fourth image (50%) the highest amount for 50%, the sixth image (83%) the highest amount for 85% progression and the seventh image (100%) the highest amount for 100% progression. The same holds true for the waterfall, although here, the votes are further spread to the corresponding neighbor images. Merely the sand basin has deviating votes as the third image (33%) received the highest amount of votes for 15% weekly progression and the fifth image (67%) for 50% progression. For the remaining percentages, the closest images got voted on most for the respective weekly progression, similar to the pond and waterfall prototypes.

6.4 Over-achievements

For each prototype almost every participant chose the seventh image (100% element progression) to represent an over-achievement of 115% goal completion. This means that a cut-off was favored over adjusting 100% in a way that it is represented by a lower element progression, such that there is room left for over-achievement. Here, the interpretation of the garden elements mimicks the behavior of virtual progress bars which end at 100% (**RQ4**).

6.5 Preferred Context

In the last task, participants were asked to order the prototypes from most favorite to least favorite for a given context (sports, education, productivity) and in a general context (**RQ5**). Additionally they were asked when they would like see the change in the element to happen. The distribution of votes is shown in Figure 6. For each context but the educational context, the sand basin received the highest amount of votes for favorite prototype, the pond for the runner-up and the waterfall for least favorite. In terms of the educational context, the pond prototype received the highest amount of votes for the most favorite prototype, the sand basin for the runner-up and the waterfall for the least-favorite. χ^2-tests on each distribution show that every distribution differs significantly from an evenly distributed voting with $p < .001$, meaning that a ranking of elements exists in each context. An additional χ^2-test reveals that there are no significant differences between the distributions for the sports, education, productivity and general context (χ^2=2.64, p=.853), meaning that contexts likely have no impact on the ranking of elements.

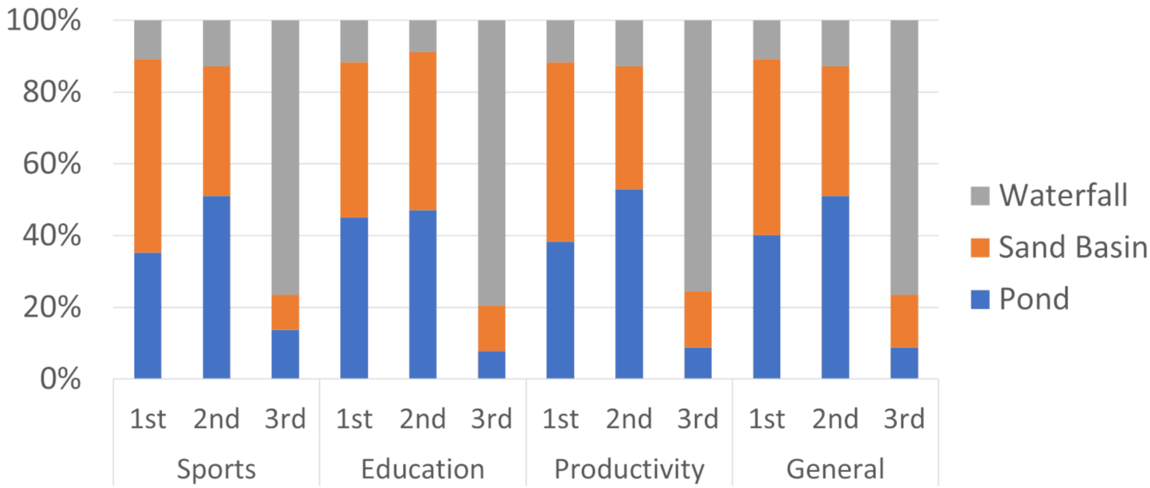


Fig. 6. Distribution of votes for most favorite to least favorite element in different contexts and in a general context.

6.6 Preferred Timing

Regarding the timing of the effect to take place (**RQ6**), seeing the effect while performing a task was favored in every context, followed by seeing the effect after finishing the task and lastly, triggering the effect on your own (see Figure 7). Again, χ^2-tests (each p $\leq$ .001) reveal that the distributions among the choices differ from an equally distributed distribution in each context. A χ^2-test between the distributions shows that they do not differ significantly from each other ($\chi^2 = 2.16$, $p = .904$). This means that contexts likely do not influence the preference when an effect is displayed on the prototypes and that in general participants prefer to see the change in the element during task execution, closely followed by seeing it after completing the task.

6.7 Gamification Preference

Lastly, we asked participants whether they would prefer a gamified application or our gamified garden if they had to choose (**RQ7**). A total of 74 (72.5%) chose the presented digital application whereas 28 (27.5%) preferred the gamified garden. The most frequently mentioned reasons for choosing the application were the increased accuracy, its omnipresent availability, simplicity and extensiveness of the displayed information. Main reasons for choosing the garden on the other hand were the physicality of the garden itself, its aesthetics, it being an ambient and social display, as well as having a relaxing nature.

7 DISCUSSION

The results of our online survey indicated several advantages and also shortcomings of our Hakoniwa prototype. Without having experienced the elements in a real world context, 27.5% of the participants would use our ambient garden display over the presented digital application (**RQ7**). Participants liked the aesthetic design of our prototype and commented on its relaxing nature. The fact that our prototype was an ambient as well as a social display, was considered a positive attribute. These insights support our initial motivation to transfer the psychological benefits of gardens and nature elements underlined by related work to gamification approaches.

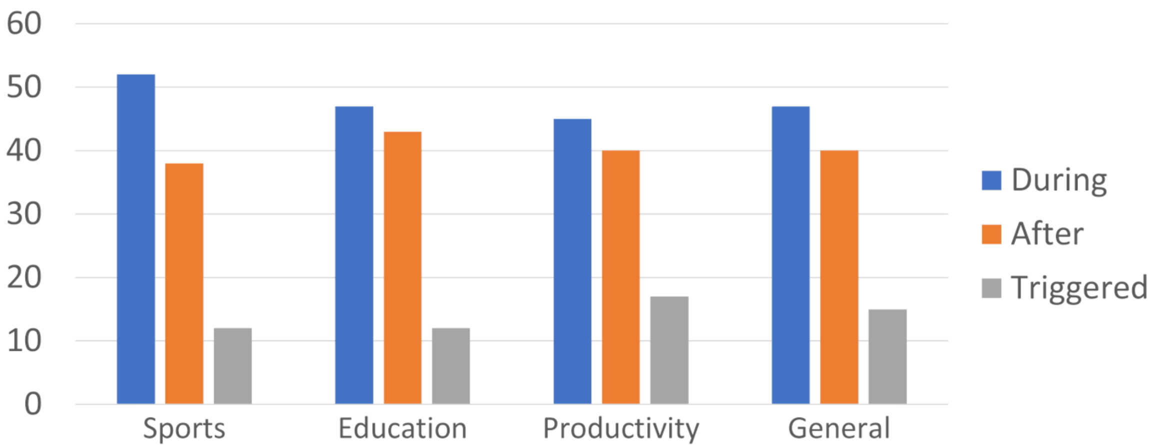


Fig. 7. Distribution of the choices made for when an effect in a garden element should show itself divided into several contexts.

The readability results of our study show that not all values were correctly interpreted by participants (**RQ3**). A major takeaway from this is the fact that, although the garden elements were intended to mimic the gamification concepts of Points and Progress, the element levels were not easily connected to their real values. Potential improvements to the elements should address clearer start and end representations, as well as additional features which users are able to better comprehend. We consider the physical abstraction from a numeric or percentile representation as a meaningful addition able to transfer the Japanese Zen garden concept of meditation and self-awareness. As there exists a high importance of data mapping between the activity data and the artifact [19], the readability of our physical prototypes might have been negatively influenced by the lack of a specific context of use. Here, as an increase of physical activity is often mapped to an increase in size of a physical representation [18, 36], our garden elements show potential for representing data such as step counting.

When asked how participants would have the garden elements represent their progress (**RQ4**), their answers indicated more linear progress representations. As the 100% completion level of a goal was connected to a maximum element representation, participants did not indicate that the garden elements should leave space to promote over-achievement of goals. Motivated by some participants' comments, future improvements of our elements could motivate over-achievements through extra features inside the pond, e.g. fish, or additional features surrounding the element, e.g., growing plants. In general participants prefer to see the change in the element during task execution, closely followed by seeing it after completing the task (**RQ6**). Similar to related work, our prototypes could support specific moments of interaction for reflecting on the represented progress [31].

In terms of perceived persuasiveness, participants indicated our prototypes to fall within a mid-range (**RQ1** & **RQ2**), regardless of context (**RQ5**). When compared to a digital gamification prototype, the digital representation of our garden elements was not able to outperform the digital counterpart. We suspect these results to partially originate from the manner in which the elements where presented., i.e., the re-digitalization of our physical elements due to COVID-19 limitations. By reverting to an online survey design, participants were unable to experience the key element of our approach, i.e., the physicality of the gamification, which could have biased a preference for a known digital approach. While the values for the perceived persuasiveness of for our prototypes are lower than those of the digital mock-up, they do fall within the range of different approaches shown in literature, e.g., [3, 38].

Based on our findings, we highlight 5 implications to improve our prototypes for future investigations, i.e., (1) elements should have a clear start and end point, (2) intermediate progress should be clearly noticeable, (3) progress should be depicted during task performance; (4) additional features are preferred to highlight achieved goals, and (5) color contrast is required to increase interpretation.

8 LIMITATIONS

While our investigation underlines some potential in using physical miniature garden representations for gamification, we would like to emphasise the limitations of the presented work. Due to the COVID-19 pandemic, we reverted to an online study design. Here, we note that this choice potentially influenced the reception of our prototypes, biasing perceived persuasiveness towards the subjective familiarity of the digital approach. Initially, we aimed to study our designs in a lab study to underline their physicality and to ensure correct readability. For future work, we aim to complete our investigation as such.

9 CONCLUSION

We presented Hakoniwa, a physical gamification prototype consisting of miniature Japanese garden elements to represent the gamification elements of Points and Progress. Hakoniwa was conceptualized to mitigate potential negative effects of gameful systems and enhance meaningfulness. To increase user engagement, we looked towards the positive psychological effects of gardens and gardening, such as stress reduction, increased life satisfaction, and increased mental and physical health.

By exploring the elements of Japanese gardens and connecting them to common gamification concepts, we derived 4 design suggestions. While many more combinations are possible, our design suggestion aims to preserve the aesthetic and meditative nature of Japanese gardens. Building upon these suggestions, we created 3 prototypes, i.e., a waterfall, a pond, and a sand basin.

In an online study, we presented our prototypes to participants ($N = 102$) and inquired about their persuasiveness and comprehensibility. In terms of persuasiveness, our prototypes were not able to match its digital counterpart. However, participants noted our prototypes' aesthetic design, and commented on their relaxing nature, and positively attributed their function as an ambient and social display.

For future work, we aim to improve on and extend our set of gamified garden elements. By taking the participants' results and comments into account, we will improve on element readability and add additional features to represent different gamification concepts. Furthermore, we will investigate our approach in a real world setting to take maximal advantage of the physical representation of the garden elements.

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