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Do users have the ability to self-repair non-complex electrical appliances? Design and development of a self-guided workshop with repair documentation in different formats

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ABSTRACT

In the context of the circular economy, repair is one of the main strategies to extend the lifespan of products. However, when it comes to non-complex and inexpensive small household electric and electronic equipment (EEE), consumers tend to not repair or self-repair these items but purchase new ones instead. The aim of this study is to analyse the self-repair experience of consumers in a three-stage self-guided workshop designed and carried out using an electric water kettle as a case study. Sixty people with different profiles participated in the self-guided workshop. An initial interview was conducted to ascertain previous repair experience, and there was also a final interview in which future willingness to repair was studied, as well as the motivations and barriers. The main stage of the self-guided workshop consisted of repairing a kettle in which two faults had been induced. Disassembly and repair guidelines were provided in three different formats (a video, step-by-step instructions and a guide). Regarding their preferences for the resource used to carry out the repair, 61.4 % preferred the video, 24.6 % the step-by-step instructions and 14.0 % the guide. The participants who successfully repaired the kettle amounted to 63.2 %, and 24.6 % of the total number of participants did not use the repair instructions. An analysis of the variable "repair success" against participants' socioeconomic characteristics showed that having previous experience of self-repair or not was the only statistically significant variable; therefore, self-reported repair experience does influence the disassembly process. Thus, the repair success rate is 40.4 % for those with previous self-repair experience against a rate of 22.8 % for those without experience. In conclusion, consumers will attempt self-repair if the information to do so is provided and it is more affordable to repair the product than to purchase a new one.

1. Introduction

The current European Circular Economy Action Plan (European Commission, 2020a) focuses on ensuring that raw materials and resources are maintained for as long as possible in the cycle of the economy. One of the product categories that this framework prioritises is that of electric and electronic equipment (EEE), promoting the extension of the lifespan of these items by incorporating measures that improve their durability, reusability, updatability and/or reparability. The European Commission (EC) is currently focusing on reparability (European Parliament, 2022) since 77 % of European citizens have stated they would prefer to repair non-working EEE rather than purchase new items (European Commission, 2014).

Regarding consumer repair, the EC has supported the right to repair (European Commission, 2020a) in order to reduce e-waste by making it possible for consumers to have their products repaired at a fair price. To this end, in order to encourage consumers to repair their EEE, the EU will spur producers to design easily repairable goods as well as to provide incentives and tools to use them for longer, such as supplying professional repairers with manuals and instructions on how to disassemble and repair their products (European Parliament, 2022).

From the producers' perspective, according to the European Commission (2022), it is observed that the proportion of SMEs that are designing products that are easier to maintain, repair or reuse varies between 6 % and 43 %, depending on the European country. Regarding resource efficiency, 27 % of SMEs plan in the short term to design

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products that are easier to maintain, repair or reuse. In addition, and with the aim of empowering consumers in relation to the right to repair, the European Parliament (2022) is developing a mandatory label which contains information on reparability. To this end, several methods to assess the level of reparability of products have been developed recently: ONR 192102 (2014), AsMer (Bracquené et al., 2018), Repair Score System, EN 45554 (2020) and the French Repair Index (Ministère de la Transition Écologique, 2021). Nevertheless, all these methods are currently mainly being applied to white goods appliances such as washing machines or vacuum cleaners, or information and communication technology (ICT) devices such as mobiles phones, tablets or televisions, among others.

From the consumer perspective, the European Commission (2017) reported that consumers would be prepared to pay more for repairable products and to choose products with better reparability performance provided that spare parts were available for at least ten years and sold at a reasonable price, repair information was made available by manufacturers free of charge and components were standardised. In addition, the European Commission (2020b) reported that almost 80 % of the consumers stated that manufacturers should be required to make devices easier to repair or easier to replace broken components. Furthermore, the EC underlines the need to promote repair facilities to discourage consumers from opting to replace a product instead of repairing it (European Parliament, 2022). Despite this new regulatory framework and actions derived from it, repair information is usually oriented towards professional repairers and tends to underestimate the role of consumers' practices and habits.

The declared willingness to repair by consumers ranges from 58 % to 89 % depending on the European country (European Commission, 2014). Nevertheless, these rates are higher than the current repair rates obtained from the scientific literature. Pérez-Belis et al. (2017) and Bovea et al. (2018) obtained through a survey that only 9.6 % and 34.5 % of the Spanish population had repaired a small household EEE or ICT item, respectively, mainly due to the belief that these items are not financially worth repairing, which is in line with the conclusions from Laitala et al. (2021). Magnier and Mugge (2022) designed an online questionnaire that was implemented in several Western European countries, in which the repair rate was 60.2 % for washing machines, 27.4 % for TVs, 37.8 % for mobile phones and 30.3 % for vacuum cleaners, obtaining an average repair success rate of 9.3 %. Nevertheless, consumers are showing an increasing trend in terms of their intention to self-repair their EEE, especially small, non-complex items (European Commission, 2014). This result was also corroborated by Sandez et al. (2023), where 63.3 % of the participants in an online survey stated they would try to self-repair their kettle. The main barriers consumers face regarding self-repair are related to the scarcity of repair information available; their lack of experience and their lack of motivation to repair (European Commission, 2018; van den Berge et al., 2021); the architecture of the product itself, which normally makes it difficult to open it to repair and/or to access the damaged components (Pozo Arcos et al., 2020; Terzioğlu, 2021); or the difficulty in finding spare parts (Tecchio et al., 2019). These results are aligned with those from Sandez et al. (2023), who found that 73.9 % of consumers with a broken kettle did not try to repair or self-repair it, but if the information needed to repair were available to them, 82.3 % would try to self-repair it.

The analysis of the experience and/or predisposition of consumers to self-repair EEE is quite limited in the literature. Only a few studies were found that focused on analysing the self-repair of products, individually or in workshops. A user observational study was carried out by Pozo Arcos et al. (2021) where 24 users with and without previous experience of self-repairing EEE carried out the process of fault diagnosis for blenders, vacuum cleaners, coffee makers and a radio CD player. This study was based on three stages: familiarisation with the product of the study (2 min), fault diagnosis stage (40 min maximum) and an interview. Terzioğlu (2021) carried out a workshop with 52 participants in which they provided 103 products from different categories (small EEE, clothes, ITC, home decoration, etc.) to self-repair and, afterwards, filled in a worksheet collecting data related to the users' experience, products and the repair method followed. The results showed that self-repair is linked to three aspects: technical (knowledge, tools, etc.), user emotion (how the user confronts the repair) and emotional attachment to the product (personal worth of repairing the product). In this line, Hielscher & Jaeger-Erben (2021) found, after conducting a cultural probe methodology, eight participatory research workshops in repair and making workshops and seventeen in-depth follow-up interviews in four repair cafés in Germany, that the success of the self-repair largely depends on users' ability and their previous experience with self-repair.

All in all, the recent regulatory framework encourages producers to design products that can be repaired and consumers to repair their goods, which is linked with their willingness to do so. However, there is a gap in the academic literature regarding whether consumers have the ability or knowledge to self-repair and under which conditions they will do so. Since it is not currently mandatory for manufacturers to provide technical repair information to consumers (European Commission, 2023; European Parliament, 2022) the repair process of broken EEE is often a process of trial and error, creating a list of possible faults and testing them one by one, isolating the fault or the problem by verifying where it is located and by checking the expected behaviour of the system (Johnson, 1991), based on the user's general level of disassembly, mechanical and electrical skills as well as the level of knowledge of the product (Rasmussen, 1984).

Taking into account this context, the general aim of this paper is to explore the self-repair experience of consumers, using electric water kettles as a case of study. To this end, three specific objectives were defined: first, to investigate whether people can repair a kettle or not; second, to identify user preferences regarding the format they prefer to receive the repair instructions in; and third, to determine their future willingness to repair after the workshop experience. To this end, a self-guided workshop was designed and implemented in Castellón (Spain) from June to September 2022, with the aim of answering the following research questions (RQ): RQ1 – What type of repair information do users need to carry out the self-repair of their small and non-complex broken EEE? RQ2 – Can consumers increase their self-repair rate if they are provided with the necessary repair information? RQ3 – If the repair information is provided, what are the main barriers to self-repair?

To fulfil this objective, this paper has the following sections: Section 2 describes the method followed to design the self-guided workshop and its development; Section 3 describes the results from the self-guided workshop; Section 4 provides the discussion of the results; and the final section presents the conclusions.

2. Method

In this section, the method proposed to design and develop the self-guided workshop is presented (Fig. 1). First, the product category and a specific product model within it are chosen. Then, the documentation related to the repair of the product category and model is reviewed from two different perspectives: identification of common failures/failing components and the repair information publicly available. These help to select the failure/s to induce in the product and in the design of the repair documentation, respectively. The next stage is the design of the three stages of the self-guided workshop (initial interview, product repair activity and final interview) and the timing for each one. Finally, the self-guided workshop is developed and implemented with a representative sample of users.

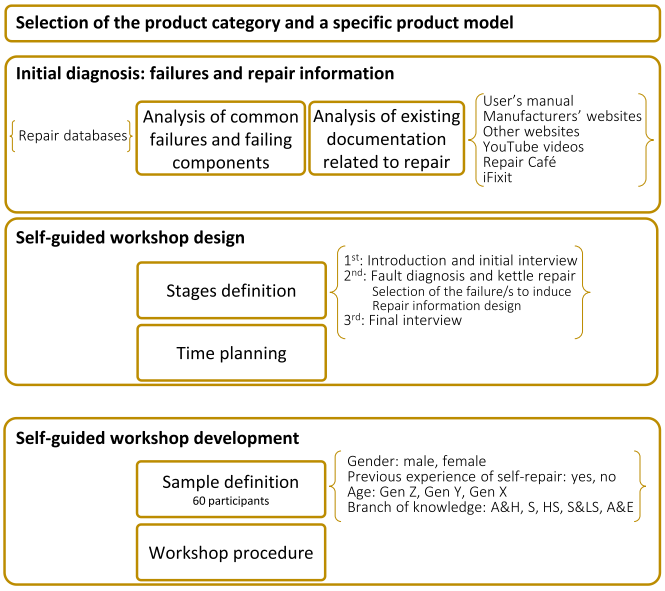

Fig. 1. Research method design.

2.1. Selection of the product category and a specific product model

Since the main objective of the study is to explore whether consumers are capable of self-repairing non-complex small EEE if they have the necessary information to do so, the product category must meet the following requirements:

- Belong to the EEE product category, prioritising small items proposed by the Ecodesign Working Plan (European Commission, 2020c).
- Have low average market price, meaning consumers usually replace the product rather than repair it when it stops working (Laitala et al., 2021; Pérez-Belis et al., 2017).
- Be a non-fashion product, so that new ones have similar aesthetics and functionality (Cox et al., 2013).
- Have a minimum safety risk while repairing.
- Have a non-complex design, since it has to be easily disassembled and assembled by users.
- Be able to be disassembled and reassembled using common tools.

From this list of requirements, and according to the European Commission (2016), the main product categories are small white goods (domestic toasters, electric kettles, non-tertiary coffee machines and vacuum cleaners), comfort fans and hair dryers. Of these, the product category chosen was that of electric water kettles (from here on, kettles) since it satisfies all the requirements and is an appliance that is present in most European homes (91 % (European Commission, 2020d)).

The market share for kettles has been stable over the last decade, and according to the European Commission (2020b) and Statista (2021), the most common characteristics of household kettles are as follows: cordless (85 %), concealed heating element (84 %), jug-shaped (96 %), auto switch-off (93 %) and without temperature holding (94 %), as well as being made from metal (44 %). Taking into account all these characteristics, the selected model is shown in Fig. 2.

2.2. Initial diagnosis: failures and repair information

2.2.1. Analysis of the most common failures and the most frequently failing components

The four repair databases made available by Open Repair Alliance (2021) were reviewed in order to identify the most common failures and failing components in kettles. Detailed results are given in Table 1. It is observed that 53.1 % of the broken kettles were repairable. The reason for failure was only reported in 53.0 % of the cases. Of these, the most common descriptions of failures were "do not heat" (34.1 %), "do not stop boiling or stop before boiling the water" (26.1 %) and "do not work" (9.9 %). Table 1 reports the most common failing components in kettles, reported in 51.8 % of the cases: thermal switch and bimetal or fuse (27.7 %), electromechanical components such as wires or power controllers (24.5 %) or the on/off switch (15.2 %).

Table 1
Percentage of failure of the components of a kettle (Open Repair Alliance, 2021).

	Database				Total
	Anstiftung	FixitClinic	RepairCafe	Restart	
Thermal switch / bimetal / fuse	26.22 %	50.00 %	9.16 %	13.24 %	27.66 %
Electronic / mechanical component	13.12 %	50.00 %	13.15 %	9.65 %	24.47 %
On/off switch	13.12 %	0.00 %	30.27 %	26.51 %	15.20 %
Heating element	16.39 %	0.00 %	8.37 %	10.85 %	8.27 %
Lid	9.83 %	0.00 %	12.75 %	8.43 %	7.18 %
Cord	9.83 %	0.00 %	5.98 %	13.24 %	6.22 %
Base plate	4.92 %	0.00 %	2.39 %	6.04 %	2.88 %
Limescale build-up	0.00 %	0.00 %	11.16 %	0.00 %	2.80 %
Sealing / window	3.28 %	0.00 %	3.59 %	2.42 %	2.18 %
Safety screws	3.28 %	0.00 %	3.18 %	1.19 %	1.89 %
Housing	0.00 %	0.00 %	0.00 %	8.43 %	1.26 %

2.2.2. Analysis of existing documentation related to repair

A systematic review of the information available to consumers regarding the repair of the kettle was performed using the following information sources:

- User's manuals. They are provided inside the packaging together with the product. The user's manuals for eleven kettles were analysed (see detail in Table S1.1 of the Supplementary Material). None of them had any type of information related to repair (main or common failures, spare parts or how to identify the broken part, etc.), as was also concluded by Pozo Arcos et al. (2022), who analysed 150 user's manuals of 48 brands available on the European market. Information is mainly related to how kettles are used, basic maintenance, how to use the guarantee and how to dispose of the appliance.
- Manufacturers' websites (official websites). They offer information about the purchase price and main characteristics (material, functionalities, etc.). Spare parts are only made available by one official manufacturer website who sell the base plate with cord as a spare part. Other spare parts such as the thermostat, base moulding, handle, resistor or filter can be found on other non-official spare parts websites.
- Other websites. A general search was performed using the following keywords in internet browsers: "water kettle" and "repair*", both in English and Spanish. The information found was related to the general use and maintenance of kettles, what to do if a kettle leaks or how to descale it.
- YouTube videos. Using the terms "water kettle" and "repair*" as a string search, forty videos were found on YouTube, both in English and Spanish, with no differences observed in the content of the videos depending on the language. The average length of the videos is over 10 min. Most of them are unedited, showing an image of the kettle to be repaired and the person describing the steps followed to disassemble, repair and assemble the kettle. The failures were mainly electrical (in the water container), although there were also videos on how to descale a kettle, how to fix the on/off switch or how to fix a

leak. Full results of the analysis can be found in Table S1.2 of the Supplementary Material.

- Repair Café (Repaircafe, 2022). This is a non-profit organisation that organises meetings where volunteers help to repair different types of product such as small household appliances, ITC or everyday products (bikes, clothes, small furniture items, etc.) (Moalem and Mosgaard, 2021). No specific information was found regarding the repair of kettles.
- IFixIt (IFixIt, 2022). A platform on which guides including both graphical and text-based information are created voluntarily by users/repairers. The main aim of the platform is to help consumers to repair their own products using repair and disassembly guides that are made freely available on this website. Currently, five kettle disassembly and repair guides can be found on this platform.

2.3. Self-guided workshop design

Having considered the information obtained in the previous stages related to the repairability of kettles and the literature review of workshops related to product design, a three-stage self-guided workshop (introduction and initial interview, fault diagnosis and kettle repair, and final interview) was proposed.

The format of the self-guided workshop was drawn up after a feedback process among members of the research team. After this process, a preliminary self-guided workshop was designed and tested on three volunteers to verify that the questions in the initial and final interviews were easy to understand, relevant and comprehensible, and to verify aspects related to the faults introduced in the kettle, tools, time planning, etc.

2.3.1. Stages

First stage: Introduction and initial interview

The first stage consisted of welcoming the participant and giving a brief introduction to the motivation and objective of the self-guided workshop. Then the participants had to sign the informed consent form and answer an initial interview, which was audio recorded, the aim of which was to determine their habits and previous experience with regard to repair. The final version of the initial interview is reported in Table S2.1 of the Supplementary Material, which includes the changes derived from the preliminary self-guided workshop.

Second stage: fault diagnosis and kettle repair

The second stage was the main body of the self-guided workshop and consisted of an observational study in which the participants had to identify the failures induced in the product and repair them using repair documentation provided in different formats. To this end, it was necessary to select the failures to be induced and design the repair documentation to be used.

Selection of the failure/s to induce

Having considered the most common failures of the product (Table 1), a failure that did not require spare parts was chosen: an electromechanical failure consisting of the disconnection of the electrical circuit of the kettle placed on the base plate. After the preliminary self-guided workshop, an additional failure with the on/off switch was added.

Repair documentation design

Taking into account the diagnosis of the repair information described in Section 2.2.2, repair documentation was designed in three different formats:

- Video: a video lasting 9 min and 30 s, of which two screenshots can be seen in Fig. 2.
- Guide: a graphic and text document based on the Disassembly Map (DM) of De Fazio et al. (2021) (Fig. 3) along with an exploded view of the kettle (Fig. S2.3 of the Supplementary Material).
- Step-by-step instructions: a document including all the necessary steps and warnings (Fig. 4).

The three formats included the same information but displayed in different ways, explaining how to disassemble the kettle into its four main parts: handle, lid, lower part and base plate.

The type and content of each format was decided after a feedback process of the research team and from conclusions of the preliminary self-guided workshop. Initial versions of the documents can be found in Figs. S3.1 to S3.3 of the Supplementary Material along with the feedback for improvement given by each participant of the preliminary self-guided workshop.

Third stage: final interview

The self-guided workshop concluded with a final semi-structured interview, also audio recorded, with the purpose of ascertaining whether participants' willingness to repair had changed after the self-guided workshop. The final interview questions are presented in Table S2.2 of the Supplementary Material, which includes the changes derived from the preliminary self-guided workshop.

2.3.2. Time planning

Once the stages of the self-guided workshop had been defined, the duration of each one had to be set. A maximum duration of 1 h was established as a requirement.

Initially, 10 min were planned for each interview, but after the preliminary self-guided workshop, it was decided to assign 5 and 15 min to the initial and final interview, respectively, since once the self-guided workshop was over, the participants were more willing to comment and give feedback.

To define the duration of the main part of the self-guided workshop (failure identification and repair), the Ease of Disassembly Method (eDim) (Vanegas et al., 2018) was applied following the steps described in De Fazio et al. (2021) to estimate a theoretical time to take as a reference. The total time to disassemble and reassemble the kettle obtained by applying the eDim method was 10.7 min, as reported in Table 2 (full results can be found in Table S4.1 to S4.4 of the Supplementary Material).

Taking into account that the time estimated by the eDim method is that corresponding to an expert repair, it was proposed to allow the participants triple the time (35 min). This is in line with the 40 min that Pozo Arcos et al. (2021) gave the participants in their observational study. In addition, the results of Matarin et al. (2022) also shows that the

Fig. 2. Screenshots from the video.

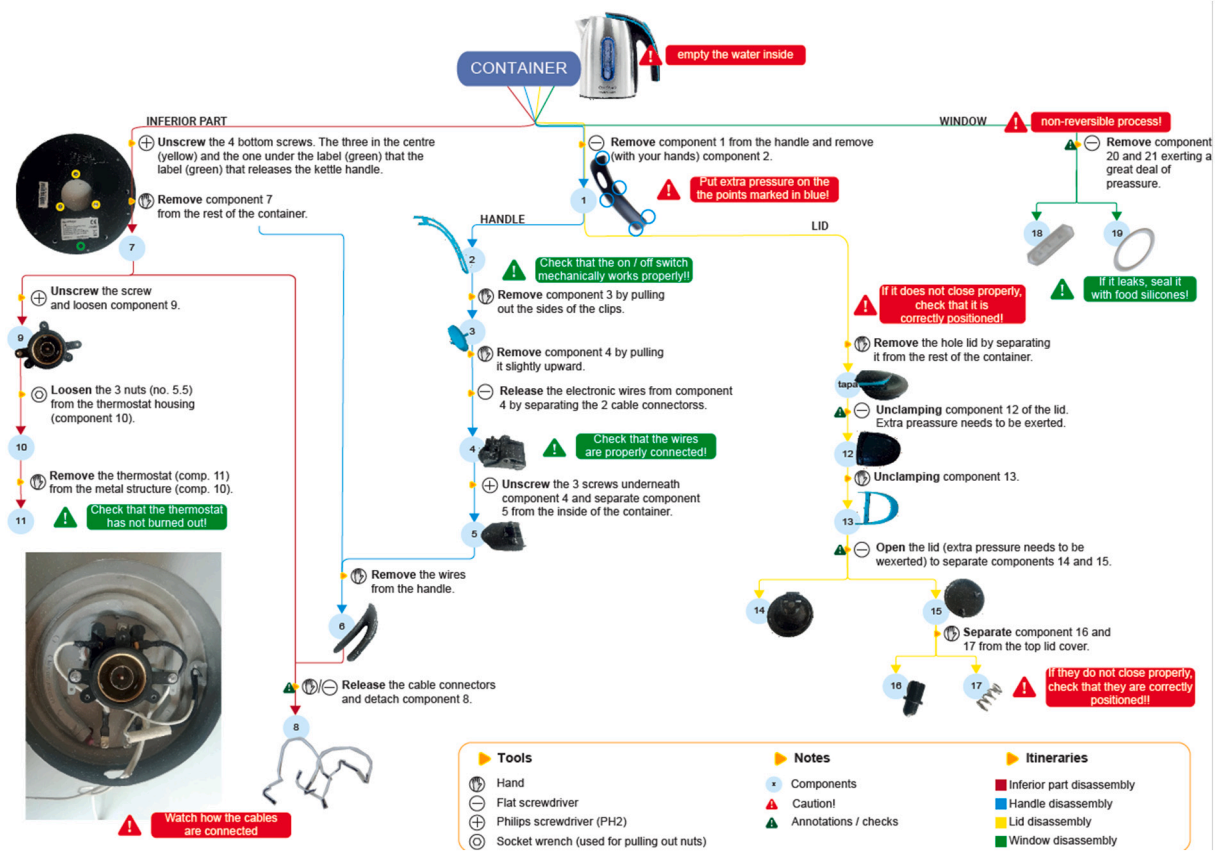

Fig. 3. Guide.

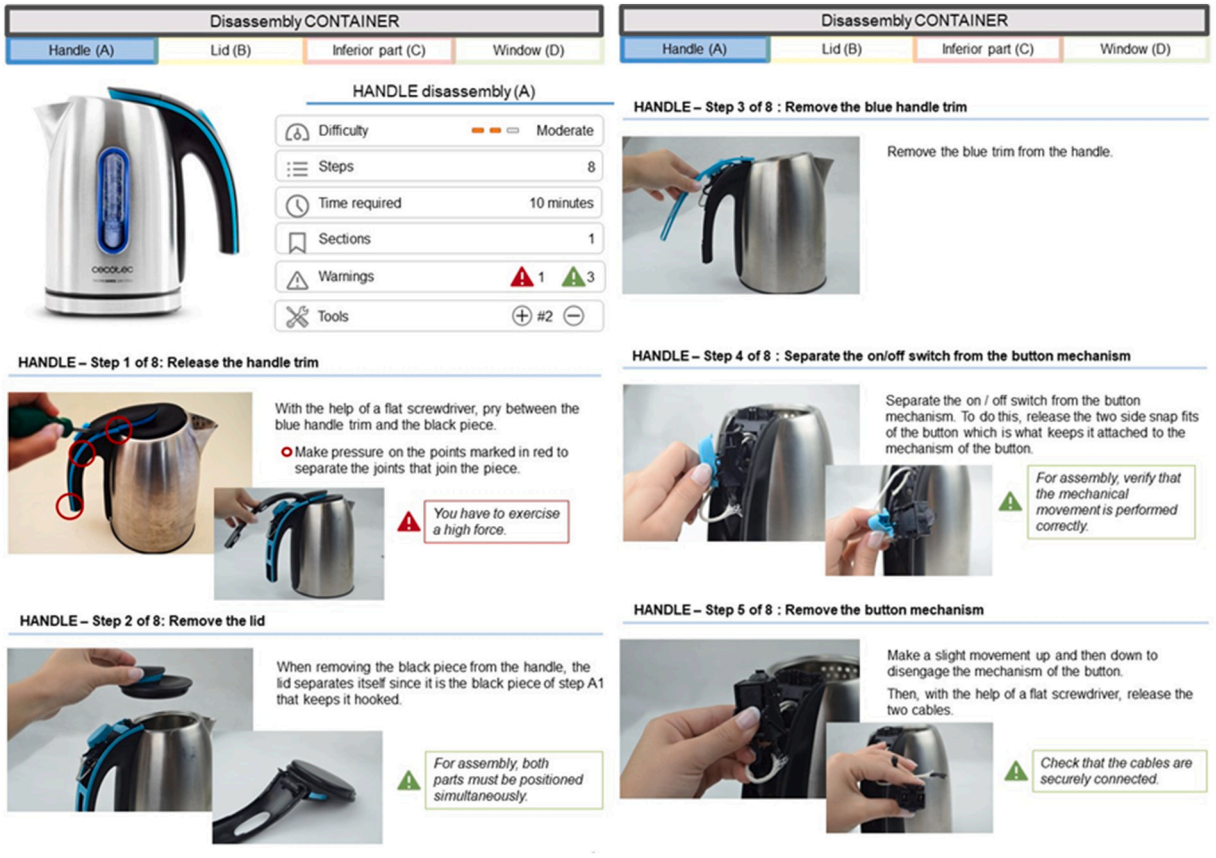

Fig. 4. Step-by-step instructions.

Table 2
Disassembly and reassembly time of the kettle model based on the eDim method.

	Disassembly (s)	Reassembly (s)	Total (s)
Base plate	56.7	87.8	144.5
Inferior part	127.1	160.4	287.5
Handle	57.5	81.1	138.6
Lid	30.8	39.1	69.9
TOTAL	272.1	368.4	640.5

average time to repair a product is between 15 and 30 min.

This duration was validated in the preliminary self-guided workshop from which it was also decided to define the following checkpoints:

- If the participant was stuck on the same disassembly/reassembly step for >5 min, a tip to finish that step would be given. If he/she continued without progress, he/she would be encouraged to consult some of the information provided.
- If after 20 min the participant had not discovered any of the faults, they were informed of them both.
- If after 25 min the participant had only discovered the first fault (either the one in the base plate or the one in the handle), they were informed of the other fault.
- If the participant had not finished after 35 min, they were asked to stop.

To collect as much information as possible from the process, the "thinking aloud" method (Hoppmann, 2009; Whalley and Kasto, 2014) was used, in which participants were asked to freely express aloud their thoughts and opinions while repairing the kettle. Everything done on the workbench was video and audio recorded. The person in charge of recording the self-guided workshop interacted as little as possible with the participant so as not to influence any kind of task, as recommended by Pozo Arcos et al. (2021).

2.4. Self-guided workshop implementation

The implementation of the self-guided workshop had the approval of the Ethical Commission of the Universitat Jaume I (CD/69/2022) and consisted of the sample definition and selection and the actual realisation of the self-guided workshop with the chosen participants.

2.4.1. Sample definition

Other similar observational studies described in the literature applied a sample of 24, 32 or 52 participants, according to Pozo Arcos et al. (2021), Hielscher & Jaeger-Erben (2021) and Terzioğlu (2021), respectively. In addition, and according to Jaeger-Erben et al. (2021) and Laitala et al. (2021), the sociological feature that most influenced and motivated the willingness to repair was related to previous repair experience. In addition, the gender, age and the study area were also studied.

With this approach, a sample of 60 participants ($2 \times 3 \times 5 \times 2$) with high-secondary or university level of education, distributed as follows, was chosen:

- Gender [2]: male, female.
- Age [3]: Gen Z (born between mid-1990s to 2010), Gen Y or millennials (born between early 1980s and mid-1990s) and Gen X (born between mid-to-late 60s to early 1980s) (De Cooman and Dries, 2012). These three generations are characterised, among other aspects, by the relationship they have with respect to the great advances in ITC and, in particular, with respect to the internet and social networks (Herrando et al., 2019).
- Branch of knowledge [5]: arts and humanities (A&H), sciences (S), health sciences (HS), social and legal sciences (S&LS) and architecture and engineering (A&E), according to the classification used in Spain to organise the degrees into higher education/university level, as well as the professional skills that stem from these branches.
- Previous experience of EEE self-repair [2]: with or without expedience. To classify a participant in the "with experience" group, he/she had to have previously tried to repair (with or without success), at least two EEE.

Table 3
Distribution of the sample by the different profiles.

	Gen Z		Gen Y		Gen X	
	A	B	A	B	A	B
A&H	P1/P2	P3/P4	P21/P22	P23/P24	P41/P42	P43/P44
S	P5/P6	P7/P8	P25/P26	P27/P28	P45/P46	P47/P48
HS	P9/P10	P11/P12	P29/P30	P31/P32	P49/P50	P51/P52
S&LS	P13/P14	P15/P16	P33/P34	P35/P36	P53/P54	P55/P56
A&E	P17/P18	P19/P20	P37/P38	P39/P40	P57/P58	P59/P60

The coding used for each participant is shown in Table 3 (P1, ..., P60). The two participants in each cell (Px/Py) correspond to participants with the same profile for age, branch of knowledge and previous experience, but differentiated by gender (x: female, y: male).

2.4.2. Self-guided workshop procedure

Volunteers were recruited through calls on various social and professional networks, as well through the distribution of an online questionnaire. After sorting the volunteers into different profiles, the selected participants were contacted and invited to participate in the study. Once all the participants had been selected, they were individually summoned to a small office at the university for a meeting lasting 1 h, where they found a table with the kettle, its packaging and user's manual, different screwdrivers and a 10.1″ tablet with the repair documentation in the three different formats described above. Before starting with a new participant, the kettle was disassembled and it was checked that all the components were working. Subsequently, the selected failures described above were induced.

A short conversation was started to break the ice and, after a few sentences, the self-guided workshop itself started. First the initial interview was conducted, and then the participant was told that he/she was going to use the kettle that morning and that it did not work and that he/she had to repair it and reassemble it to be able to use it again. After 35 min, the main stage of the self-guided workshop finalised and the final interview was conducted, in which comments and feedback were collected from each participant.

During the first and last stage of the self-guided workshop, the initial and final interview, the organiser set up the audio recorder and interacted with the participant to ask the questions as well as to request further explanations if the answer was vague or not self-explanatory. During the second stage of the self-guided workshop (fault diagnosis and kettle repair) the organiser just interacted with the participant at the beginning to give the main instructions. Then, a video camera was set to audio and video record what the participant was doing, while the organiser took notes of the whole process.

After each participant, the answers from both interviews were transcribed and coded in order to analyse the responses. The activities of the second stage (failure identification and repair) were registered each 10 s, noting the times at which each of the actions in the process was carried out by each participant.

Before starting the self-guided workshop with a new participant, the kettle was completely disassembled to check that the previous participant had assembled it properly and to verify that it was fully functional. Then, the two failures were induced again.

3. Results

3.1. Initial interview

During the initial interview, as stated in Table S2.1 of the Supplementary Material, the questions raised revealed whether the participants had previous experience of self-repair or not. A total of 64.9 % of the participants had a relative in their family that used to repair. This relative was mainly the father (54.4 %) followed by the mother (14.0 %) or an uncle (5.3 %). The participants that did not have or have not had a kettle amounted to 40.4 % (23 participants). Of these, only three participants had experienced it breaking, and only one of them had attempted to repair it.

Since motivation and ability are two of the main barriers to repair, as reflected in the literature review, all the participants were asked if they thought they were capable of repairing non-complex products, such as a kettle. A total of 82.5 % of them agreed, and the average mark they gave to their repair skills was 5.28 out of 10. If the kettle was finally repaired, 77.2 % of the participants stated they would become more attached to or fond of the repaired product. However, when asked about having to repair the kettle in reality, only 63.2 % stated that they would have tried, 28.1 % of them would have given the product to a relative or acquaintance to repair it, and only 33.3 % of the participants would have taken the kettle to a repair centre.

When it comes to spending money on the repair, 33.3 % of the participants would change the kettle directly if the new product cost were €20, while 10.5 % would do so if the cost were 50€. The average amount of money spent on repair if the purchase price were €20 would be €8.80 ± 3.36; while if the purchase price were €50, the amount spent would be €18.63 ± 7.10. Participants were also asked about the expected average lifespan of the kettle. The average number of years that participants supposed a kettle would last was 7.8 ± 5.6, while the mode was 10 years.

Regarding the repair documentation that consumers usually use when making repairs, 59.7 % of the participants stated that they examine the user's manual. However, they also stated that they usually use it in second place, after first searching for information on the internet. A total of 77.2 % of the participants stated that they keep user's manual for small household EEE, while 35.1 % said that they keep the packaging.

3.2. Failure diagnosis and kettle repair

During the second stage, participants had to identify why the kettle was not working and try to repair it. As stated, the maximum time to accomplish this task was 35 min and two failures had to be identified and repaired: the base plate and the on/off switch. The results were first analysed descriptively and then were statistically modelled by Generalised Linear Models (GLM) in order to identify the socioeconomic variables (Table 4) that significantly influenced them.

3.2.1. Descriptive analysis

Fig. S5.1 in the Supplementary Material shows the timing for achieving the various milestones in the self-guided workshop, for each participant. From it, the following results can be described.

Related to the repair documents, the most used document was the video (43.9 %), followed by the step-by-step instructions (22.8 %) and lastly the guide (8.8 %). However, 24.6 % of the participants did not use any documentation to repair the kettle. The user's manual was used by 29.8 %, but the use time of this document was under 1 min. Despite the fact that 75.4 % of the participants used some type of documentation, 29.8 % of them did not really pay attention to it, since they only skimmed it.

Related to the failures induced, 56.1 % of the participants identified the on/off switch failure first, while 42.1 % identified the base plate failure first. The participants who did not find either of the two failures amounted to 1.8 %. The number of participants who were told aloud the failure of the base plate and the on/off switch was 35.1 % and 12.3 %, respectively, according to the checkpoints established in the methodology. The percentages of repairing the base plate and the on/off switch were 89.5 % and 86.0 %, respectively, while the kettle was repaired by a total of 63.2 % of participants, as can be seen in Fig. 5. From all the participants, 15.8 % disassembled the kettle and carried out all the steps following the documentation methodologically but were not able to reassemble the kettle in time. Those requiring help at some point amounted to 49.1 %, since they were stuck on the same step for 5 min. The main instructions given were on how to reassemble the housings of the base plate (54.4 % struggled with this step) and how to disassemble or reassemble the handle (56.1 % struggled with this step).

The tools were correctly used by 64.9 % of the participants, but 35.1 % of them did not disconnected the base plate from the mains before disassembling this component, and 14.0 % of the participants were stopped for safety reasons: for instance, trying to test if the kettle was working without replacing the casing, or touching the wires.

When checking if the kettle had been repaired, 26.3 % of the participants reassembled the kettle completely, and 26.3 % poured water inside before connecting it. The success repair rate was 63.2 %. Fig. 5 shows the success repair rate for the socioeconomic variables reported in Table 4.

The general feeling was that 89.5 % of the participants were

Table 4
Distribution of the sample by socioeconomic characteristics.

Variable	Range	Proportion of the total (%)
Gender	1. Female	50.00 %
	2. Male	50.00 %
Age	1. Generation X	33.33 %
	2. Generation Y	33.33 %
	3. Generation Z	33.33 %
Household income	1. <€1000	1.75 %
	2. €1000–2500	31.58 %
	3. €2500–4000	49.12 %
	4. >€4000	17.54 %
Branch of knowledge	1. Arts and humanities (A&H)	19.30 %
	2. Sciences (S)	21.05 %
	3. Health sciences (HS)	17.54 %
	4. Social and legal sciences (S&LS)	21.05 %
	5. Architecture and engineering (A&E)	21.05 %
Previous experience with self-repair	1. Yes	50.00 %
	2. No	50.00 %
Existence of a reference person who repairs	1. Yes	64.91 %
	2. No	35.09 %

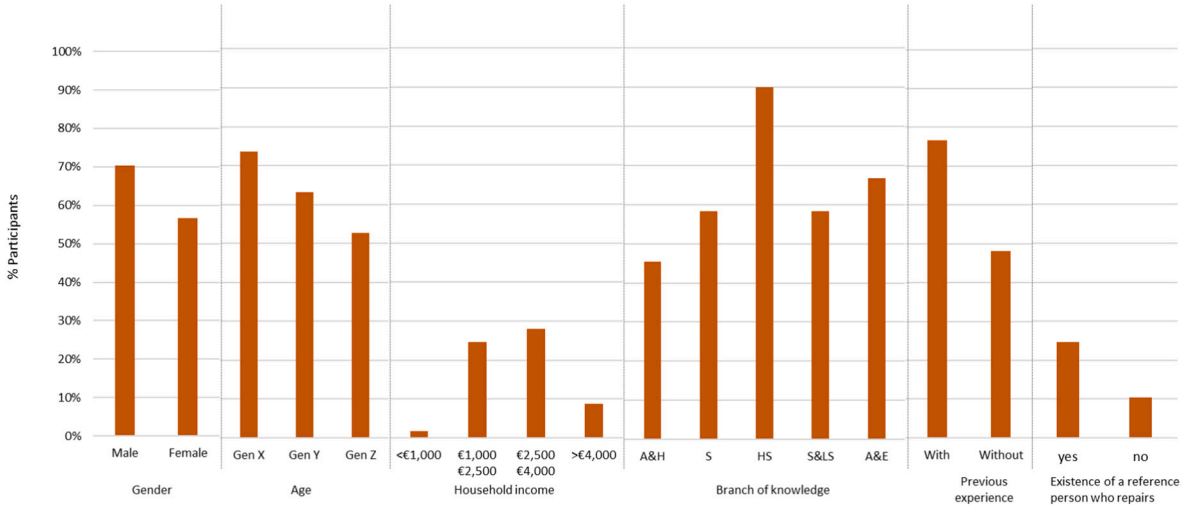

Fig. 5. Success repair rate in the second stage depending on each socioeconomic variable.

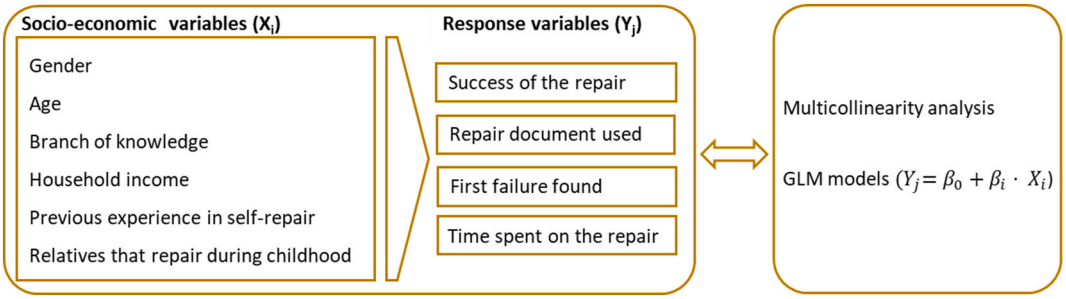

Fig. 6. Statistical analysis approach of the second stage of the self-guided workshop.

confident of their abilities, and 75.4 % seemed driven and did not hesitate significantly. Those that had a general idea where the failure could be amounted to 63.2 %, and they did not disassemble any more than was necessary, such as the lid. For those participants who did not manage to repair the kettle (36.8 %), if 5 more minutes had been given, 24.6 % of them would have reassembled the kettle fully and correctly, so it would function properly.

3.2.2. Statistical analysis

In order to supplement the descriptive analysis of the obtained results of the failure identification and kettle repair, an analysis was carried out to evaluate the influence of the socioeconomic variables given in Table 4 (age, gender, branch of knowledge, household income, previous experience of self-repair and existence of a person of reference who repairs) on the following results (response variables): success of the repair, repair document used, first failure found and time spent on the repair, as shown in Fig. 6.

The data were statistically processed with R software (R core team, 2021; The Jamovi Project, 2021), following the methodology outlined in Fig. 6.

Before developing the statistical models, the multicollinearity among the socioeconomic variables was explored in order to identify whether any socioeconomic variable depended on any other and to consider the possibility of excluding any variable from the models (Kutner et al., 2004). To this end, the Variance Inflation Factor (VIF) was calculated. It quantifies the severity of multicollinearity in an ordinary least squares regression analysis and provides an index that measures how much the variance (the square of the estimate's standard deviation) of an estimated regression coefficient is increased because of collinearity. If the value is high, it can be assumed that the variables are related and these should then be excluded from the model. The results of the multicollinearity analysis are given in Table 5. As the VIF is near to 1, none of the socioeconomic variables can be omitted for the statistical analysis.

Then, Generalised Linear Models (GLM) (Gallucci, 2019) were applied in order to identify the socioeconomic variables (X_i) that significantly influence each response variables (Y_j) in accordance with Eq. (1):

$$Y_j = \beta_0 + \beta_i \cdot X_i \quad (1)$$

where Y_j represents each variable response, β_0 is a scalar that represents the intercept, and βi are the coefficients of the linear effects of each socioeconomic variable (X_i) on each response variable (Y_j).

Table 6 presents the GLM models for each variable response, where the significant socioeconomic variables have been highlighted in bold for each response variable. It can be concluded that for the response variable "success of the repair" there are statistically significant differences for the socioeconomic variable "previous experience of self-repair" and to a lesser extent for "branch of knowledge". For "repair document used" and "first failure found" there are only statistically

Table 5
General lineal model – success or failure of repair against socioeconomic variables.

Socioeconomic variable	VIF	Tolerance
Gender	1.0991	0.9099
Age	1.0806	0.9254
Household income	1.1312	0.8840
Branch of knowledge	1.0693	0.9352
Previous experience of self-repair	1.2589	0.7943
Existence of a reference person who repairs	1.1817	0.8463

Table 6
GLM models and results.

		Socioeconomic variable (X_i)	Effect	$\beta_i \pm$ 95%confidence interval; sd
Variable response (Y_j)	**Success in the repair**	Age	Gen Y – Gen Z	[−0.1053 ± 0.1582;0.509]
			Gen X – Gen Z	[−0.2105 ± 0.1582;0.189]
		Gender	Female – Male	[0.1370 ± 0.1290;0.293]
		Branch of knowledge	S – A&H	[−0.1288 ± 0.2016;0.526]
			HS – A&H	**[−0.4455 ± 0.110;0.040]**
			S&LS- A&H	[−0.1288 ± 0.2016;0.526]
			A&*E*- A&H	[−0.2121 ± 0.2016;0.298]
		Previous experience of self-repair	**Without experience – with experience**	**[0.2850 ± 0.1245;0.026]**
		Household income	€1000–2500 - < €1000	[0.222 ± 0.4983;0.657]
			€2500–4000 - < €1000	[0.4286 ± 0.4936;0.389]
			>€4000 - < €1000	[0.5000 ± 0.5087;0.330]
		Reference of a person who repairs	Yes – no	[−0.1054 ± 0.3770;0.1662]
	Repair document used	Age	Gen Y – Gen Z	[0.1053 ± 0.4044;0.796]
			Gen X – Gen Z	[0.3158 ± 0.4044;0.438]
		Gender	Female – Male	[−0.5074 ± 0.3224;0.121]
		Branch of knowledge	S – A&H	[0.9015 ± 0.4740;0.063]
			HS – A&H	**[1.8182 ± 0.4962;<0.001]**
			S&LS- A&H	**[1.0682 ± 0.4740;0.028]**
			A&*E*- A&H	**[0.4740 ± 0.1170;0.028]**
		Previous experience of self-repair	Without experience – with experience	[−0.6185 ± 0.3188;0.058]
		Household income	€1000–2500 - < €1000	[−1.5000 ± 1.2370;0.231]
			€2500–4000 - < €1000	[−2.1429 ± 1.2253;0.086]
			>€4000 - < €1000	[−1.900 ± 1.2628;0.138]
		Reference of a person who repairs	No – yes	[0.0149 ± 0.6761;0.966]
	First failure found	Age	Gen Y – Gen Z	[−0.1053 ± 0.1695;0.537]
			Gen X – Gen Z	[−0.3158 ± 0.1695;0.068]
		Gender	Female – Male	[0.0778 ± 0.1414;0.585]
		Branch of knowledge	**S – A&H**	**[−0.4848 ± 0.2136;0.027]**
			HS – A&H	[−0.4182 ± 0.2236;0.067]
			S&LS- A&H	[−0.0682 ± 0.2136;0.751]
			A&E- A&H	[−0.1515 ± 0.2136;0.481]
		Previous experience of self-repair	Without experience – with experience	[0.1333 ± 0.3188;0.058]
		Household income	€1000–2500 - < €1000	[0.6667 ± 0.5477;0.229]
			€2500–4000 - < €1000	[0.5357 ± 0.5426;0.328]
			>€4000 - < €1000	[0.7000 ± 0.5592;0.216]
		Reference of a person who repairs	No – yes	[−0.0716 ± 0.1481;0.630]
	Time spent in the repair	Age	Gen Y – Gen Z	[−284.1667 ± 189.4073;<0.001]
			Gen X – Gen Z	[−172.3077 ± 186.2591;0.144]
		Gender	Female – Male	[141.5278 ± 148.3568;0.347]
		Branch of knowledge	S – A&H	[−184.0000 ± 263.2899;0.490]
			HS – A&H	[68.5000 ± 247.8792;0.784]
			S&LS- A&H	[174.5714 ± 254.5980;0.498]
			A&*E*- A&H	[213.5000 ± 247.8792;0.396]
		Previous experience of self-repair	Without experience – with experience	[267.1212 ± 149.8789;0.084]
		Household income	€1000–2500 - < €1000	[9.2308 ± 456.9920;0.984]
			€2500–4000 - < €1000	[−174.0000 ± 454.8106;0.705]
			>€4000 - < €1000	[48.0000 ± 482.3995;0.921]
		Reference of a person who repairs	No – yes	[144.5055 ± 152.4036;0.350]

In bold, significant socioeconomic variables.

significant differences for “branch of knowledge”, while for “time spent on the repair” none of the socioeconomic variables are significant.

3.3. Final interview

Once the second stage had ended, either because the participant had successfully repaired the kettle or because the 35 min had expired, the final interview was carried out following the script in Table S2.2 of the Supplementary Material. The average time of the final interview was 9.83 ± 4.00 min, ranging from 4.5 min to 20.45 min.

First, the participants were told to have a look at the three documents and select the one they would find the most useful in trying to self-repair a small EEE. A total of 61.4 % of the participants preferred the video, 24.6 % the step-by-step instructions and 14.0 % the guide; however, these documents were not those chosen to repair the kettle. In Fig. 7, the X-axis shows the distribution of the materials that the participants used during the second stage of the self-guided workshop. Inside each bar (in Fig. 7) the distribution of the material chosen as the preferred one for self-repair as stated during the final interview is shown. For instance, the video was used during the second stage by 43.9 % of the participants, while in the final interview 96.0 % of them continued to choose the video while 4.0 % of them preferred the guide. In addition, 47.4 % of the participants declared that they would have preferred to have the documents in paper format, although only 15.8 % would have printed the document if it only came in a digital format. During the first interview, 77.2 % of the participants had already stated that they kept the user’s manual for this type of household appliance, while 86.0 % of them indicated in the final interview they would have kept it if the repair information had been included in the user’s manual. A total of 80.7 % of the participants declared that they owned the same basic tools as those used during the self-guided workshop.

When asked if they would try to repair their kettle after the self-guided workshop if they were given the corresponding information, 89.5 % of the participants would do so with the same confidence they had shown during the self-guided workshop. The participants scored their ability to repair during the first interview and their feelings towards repair after the second stage (on a scale of 10 points). During the first interview, the average was 5.28 ± 2.15, while in the final interview it was 6.32 ± 2.07, where 64.91 % of the participants gave themselves a higher mark after the self-guided workshop.

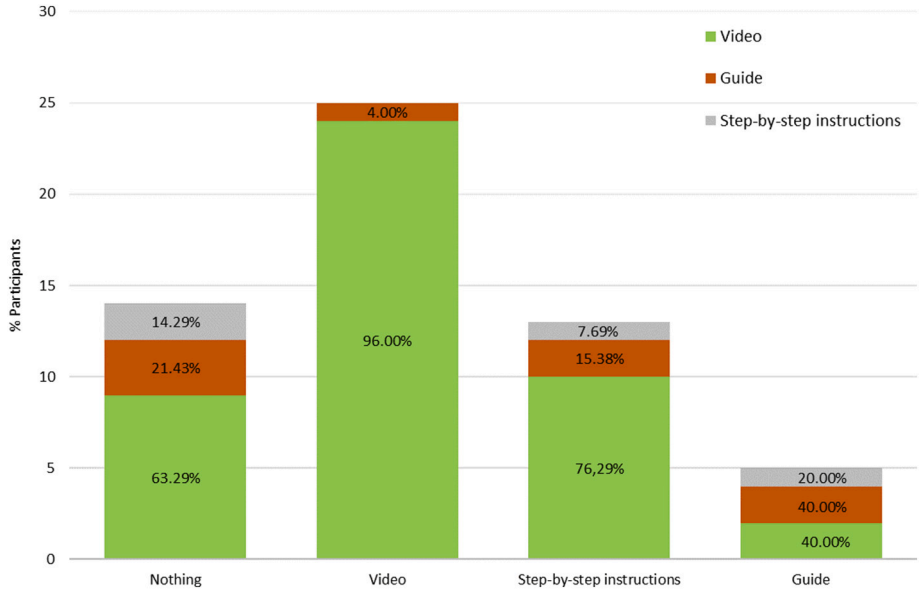

Fig. 7. Material used during the second stage and the preferred document format stated during the final interview.

Table 7
Strengths, weaknesses and improvement measures related to the three repair documents.

	Strengths	Weaknesses	Improvement measures
Video	It orally explains how to make the repair. It is easy to reproduce.	It is too fast, and it is difficult to follow the steps. It is too long: feeling of wasting time. It is not fully displayed, and so it is easy to make a mistake. It does not allow participants to think about what they are doing or why they are doing it. They just follow the steps.	Improve the quality of some images. Add some static images related to the critical parts. Create the model in 3D software.
Guide	The information is given in three pages. It is easy to follow, although the first impression is that it is a complex document.	It is difficult to figure out how to start. All the information is given in three pages. It is complicated to find the exact component to remove.	Place the legend at the top of the page. Improve the quality of some pictures.
Step-by-step instruction	It is a complete and well-explained document, both in text and images. It has a clear structure that makes it easy to follow. It is a straightforward document and quick to read.	It lacks an index to guide the users. It is too long.	Include an index with the parts and steps. Include a general overview of all the components and their names.

During the final interview, participants were also encouraged to give feedback related to the three formats of the repair documents, their first impression and how to improve them. The most frequently made comments are detailed in Table 7.

Overall, with regard to the documents, 21.1 % of the participants expressed they lacked a list of possible failures and how to solve them. Furthermore, 21.1 % of them would also have preferred documents detailing reassembly in addition to those on disassembly. In general, the cautionary advice given was helpful to those who read it, but the general impression is that people do not usually read instructions with their full attention. In relation to the user's manual, 64.9 % of the participants stated that they did not use it since, based on their previous experiences, it is not helpful for repairs.

Participants were also asked why they did not self-repair, and the results showed that 22.81 % of them lacked self-confidence, 15.8 % lacked the necessary skills, and 24.6 % lacked time. Related to the most common barriers to repairing, 40.4 % of the participants mentioned the high cost of the repair compared to the cost of a new appliance and 14.1 % mentioned the lack of availability of spare parts. The main measures to encourage society to repair suggested by the participants were as follows: making repair information public and free (35.1 %), awareness campaigns (29.8 %) and labelling products designed for repair (19.3 %). Last but not least, 24.6 % of the participants indicated that there is a general lack of education not only on how to repair, but also of general knowledge on how the products work, how to disassemble/reassemble them, etc. They propose as possible solutions providing training on basic disassembly skills, repairability and household fixes, either in regular, compulsory education or by some other means. The average time of the final interview was 9.83 ± 4.00 min, varying from 4.50 min to 20.45 min.

4. Discussion

The aim of this study was to determine whether consumers have the ability to self-repair non-complex, small electrical appliances such as kettles. From the self-guided workshop, it was found that 63.2 % of the participants were able to repair and reassemble the kettle in less than 35 min and using the repair documents provided. In addition, 80.7 % successfully repaired the kettle but did not have time to reassemble it within the given time. This percentage of success is higher than that observed in Pozo Arcos et al. (2021) for blenders, vacuum cleaners, coffee makers and radio CDs, and in Matarin et al. (2022) for coffee machines, although it is important to note that kettles have a much less complex product architecture than these other appliances. In addition, it is important to observe that despite the repair success rate achieved during the self-guided workshop, only one out of the three participants who had experienced a broken kettle had previously attempted to repair it. This rate is lower than the rate reported by Magnier and Mugge

(2022) for TVs (27.4 %) or vacuum cleaners (30.3 %), or by Bovea et al. (2018) for small ICTs (34.5 %), or by Pérez-Belis et al. (2017) for small household EEE (9.56 %). It should be noted that during the self-guided workshop, there are factors that can alter the behaviour of the participants compared to how they would behave at home. For example, the pressure from the participants to successfully complete the task or the pressure of being constantly supervised by a researcher. These factors may have empowered the participants, hence the high success rate achieved compared to what they may have achieved on their own at home.

The first research question (RQ1) is focused on determining which repair information consumers require to carry out self-repair of their broken, non-complex small EEE. The interviews carried out during the self-guided workshop revealed that although 77.2 % of the participants said they keep the user's manual at least during the warranty period, they normally do not use it, but prefer to perform searches on the internet. Only 35.1 % believe that user's manual can be useful for repairs. In view of this and regarding the documentation provided, the user's manual is the only document that consumers currently receive. As concluded in the repair information review by consumers, this document (the user's manual) only provides information on how to use the appliances and, usually, on some basic maintenance. There is no information regarding how to repair, the principal common failures or data about spare parts available to consumers, as was also concluded by Pozo Arcos et al. (2022). These results are in accordance with those obtained by Woidasky and Cetinkaya (2021) for laptops, who stated that 80 % of laptop users do not use the user's manual even to start it up. Regarding the repair documentation evaluated in the main part of the self-guided workshops, participants preferred the video, followed by the step-by-step instructions, and lastly the guide. As a proposal for improvement, after the interviews, it was identified that if the manufacturers provided a list of the principal common failures, along with an explanation in video format of how to disassemble and reassemble the product to repair it, this could be an incentive to encourage self-repair. These suggestions may solve the problem that these types of products are usually replaced or stored away broken, as stated by Bovea et al. (2018).

With respect to the second research question (RQ2), can consumers increase their self-repair rate if they are provided with the necessary repair information; the overall feeling after the self-guided workshop was positive since 96.5 % of the participants indicated in the final interview that they would try self-repair in the future. This is in line with the results by Jaeger-Erben et al. (2021) and Sandez et al. (2023), who concluded that society has the intention to increase self-repair activities. Additionally, participants supposed the average lifespan of kettles would be 7.77 years, which is a higher perception of their lifespan compared to their actual lifespans, which vary from 4.4 years to 6 years (European Commission, 2020d; Sandez et al., 2023).

Regarding RQ3 (If the repair information is provided, what are the main barriers to self-repair?), although participants declared willingness to improve the rates of self-repair, the barriers identified for it were in line with those reported by Bovea et al. (2018), Dangal et al. (2021), Rodrigues et al. (2020) and Sonego et al. (2022): lack of time (24.6 %), lack of self-confidence (22.8 %) and lack of knowledge or ability (15.8 %). Contrary to the conclusions from Pozo Arcos et al. (2020), the lack of removable and reusable fasteners and the lack of tools were not identified as handicaps.

However, for this case study of kettles, all these barriers occur in a context in which self-repair costs less than a new replacement. This is closely related with the price and availability of spare parts. Spare parts are also stated as a barrier by 14.0 % of the participants, in line with Laitala et al. (2021). While preparing the documentation for the self-guided workshop and searching for common mistakes, it was noticed that the base plates are not universal: they are not standard even for kettles of the same brand. Standardising components is a strategy that has already been tested and approved in order to minimise WEEE (European Commission, 2020e). New directives by the European Parliament (2022) are being introduced to force manufactures to provide spare parts at a fair price, at least to professional repairers. As concluded, since kettles are not one of the products that consumers take to a service centre for repair, it is proposed to modify the directives to consider the particular case of the products included in the subsection "Selection of the product category and a specific product model", so that both spare parts and repair information are directly available to users.

In view of the results of this study and the future directions of the legal framework related to reparability of products, several design improvement proposals can be made for kettles. Kettles, as seen in the model used in the self-guided workshop, can be easily disassembled with basic/commercial tools and with removable and reusable fasteners (except the window and the window silicone which are not removable for safety reasons) (European Parliament, 2022; Ministère de la Transition Écologique, 2021). The improvement proposals are along the lines of standardising components to increase the repair rate and reduce the amount of WEEE. Furthermore, it is proposed to rethink the criteria of "operation at low level when defective" and "operation after removing the lid" defined in ONR 192102 (2014) for the kettle product category. These two criteria may compromise the safety of consumers. Therefore, having conducted the self-guided workshop and being able to see first-hand how a sample of consumers perform, it is suggested that the idea that these two criteria benefit repairability and/or improvability be discarded.

Some suggestions for designers as well as manufacturers in order to facilitate and encourage self-repair among users can be extracted from the results of the workshop. From the feedback regarding the repair documentation received by the participants, it has been shown that the architecture of the product influences the simplicity of the repair instructions, the greater the modularity and standardisation, the greater the simplicity of the repair instructions. These instructions must be previously tested by users without prior experience in repair and without detailed knowledge of the product to be repaired, and made available both embedded in user manuals and in video format on the web. In this way, it is ensured that they are available to practically all users, covering all their preferences.

Regarding the socioeconomic variables influencing the results of the self-guided workshop, the results obtained revealed that only the "branch of knowledge" and the "previous experience of self-repair" statistically affect some results. As detailed in Section 2.4.1, all the self-guided workshop participants have high-secondary or university level of studies, regardless of their branch of knowledge. However, the significance of the educational levels has not been analysed in the GLM models due to the lack of variability of this socioeconomic variable in the selected sample. But the level of education is a recurrent socioeconomic variable analysed in surveys/interviews related to reparability (Sandez et al. (2023), Magnier and Mugge (2022), Laitala et al. (2021), Jaeger-Erben et al. (2021), Bovea et al. (2018) or Pérez-Belis et al. (2017)) but not in repair workshops (Pozo Arcos et al. (2021) or Terzioğlu (2021)). Regarding the former variable, it was found to be significant in Sandez et al. (2023), Bovea et al. (2018) and Pérez-Belis et al. (2017) for the repair of kettles and small household ICT and appliances, respectively. The remaining studies do not analyse the level of significance of socioeconomic variables. For this reason, it is necessary to incorporate this socioeconomic variable in future research.

5. Conclusions

Reparability is considered as a strategy to improve the lifespan of EEE in general and of small household EEE in particular. The legal framework related to the reparability of products has evolved rapidly in recent years. However, self-repair still remains unexplored.

In this study, a method was proposed and applied to determine whether consumers could repair their non-complex small appliances if they were provided with the necessary information to self-repair them. The implementation of the self-guided workshop provided the result

that 63.2 % of the participants managed to repair the kettle, while 17.5 % managed to identify and repair the two failures but did not completely reassembly the kettle within the allotted 35 min.

A total of 61.4 % of the participants preferred the video, 24.6 % the step-by-step instructions and 14.0 % the guide. The participants who successfully repaired the kettle amounted to 63.16 %. From the total number of participants, 24.6 % did not use any of the repair instructions and all but one of them managed to repair the kettle. An analysis of the variable "repair success" against participants' socioeconomic characteristics showed that having previous experience of self-repair or not was the only statistically significant variable; therefore, self-reported repair experience does influence the disassembly process. Thus, the repair success rate is 40.4 % for those with previous self-repair experience against a rate of 22.8 % for those without experience.

The proposed method is easily reproducible, for other kettle models and/or other failures induced and for other product categories that can be self-repaired due to their non-complex architecture, such as hair dryers, drip coffee makers, toasters, etc. In the same way, other formats of repair documentation can be tested and validated. Although the sample was selected taking into account four socioeconomic variables (age, gender, previous experience of self-repair and branch of knowledge), only one person for each profile participated in the self-guided workshop. This is a limitation of the study and as a future development, it is proposed to increase the sample size to obtain more significant results. In addition, other socioeconomic variables such as level of education or income could be incorporated into the GLM models, besides the socioeconomic variables already considered in this study (Table 5 / Fig. 7). This could be useful to focus awareness campaigns to the consumer profiles less predisposed to self-repair.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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