Case Study

How sustainable is my phone? Exploring the Fairphone's modular design concept

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Ansys Software Used

This case study uses Ansys Granta EduPack™, the set of teaching resources to support materials education.

Summary

Information and Communication Technology (ICT) devices and services account for around 20% of global energy consumption, with smartphones dominating other technologies in terms of GHG emissions. In this case study we look deeper into the concept of more sustainable mobile devices by analyzing a Bill of Materials for Fairphone proxy, using the Ansys Granta EduPack software and its EcoAudit Tool.

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1. Chasing a Sustainable Smartphone

Information and Communication Technology (ICT) devices and services account for around 20% of global energy consumption [1], with smartphones (Figure 1) dominating other technologies in terms of GHG emissions. Indeed, 1.28 billion mobile devices were sold in 2022 [2] and this is not set to slow down. This may not be a problem in itself, but it has been found that up to 70% [3] of discarded phones still function adequately! This is because consumers have demonstrated a desire to have up-to-date technology that features the cutting edge of design, processing power and device capabilities [3]. The issue is that the raw material use, and emissions associated with manufacture and transport are deeply unsustainable. This has led to 'obsolescence' being coined as a term to describe reasons that may make a mobile obsolete. In addition, we have of course waste due to a broken screen, poor battery performance or even water damage. So, it would seem reasonable to increase consumer retention, mobile phone manufacturers should aim to develop more durable, sustainably sourced, and easy to repair mobile devices.

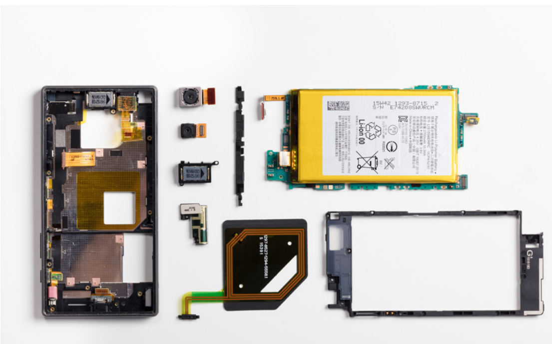

Figure 1: Standard cellphone parts

For example, the Fairphone, created by Fairphone B.V, aims to tackle each of one of the above segments [4]. The Fairphone 4 features a lifespan that is four times the market average of around 2.5 years and this is achieved by using a modular design. Modular design aims to increase the ease of repair and upgrading of a device and in doing so, increase device retention. In this case study, we try to mimic this and analyze the concept of a modular design mobile, using Eco Audit Tool for a streamlined LCI.

On average, it requires 34 kg of ore [5] to be mined to produce one smartphone. Yet, due to the design of a smartphone, it's modules can be replaced with reused or refurbished parts such that up to 73% of the materials in the phone can theoretically be recycled [6]. Furthermore, they use durable materials for the casing and glass to create a more robust and damage resistant device. Fairphone has suggested that extended use of up to 5 or 7 years reduces greenhouse emissions related to production and use by up to 31% or 45% [7] respectively compared to other mobiles. The questions remain: how many repairs does this compare to? Is the technical specification built to last for 10-years matched by operating system updates? Does the country of use matter?

Fairphone is not alone in its efforts. Indeed, other major manufacturers, such as Apple, have managed to make huge progress in improving their iPhone sustainability by reusing parts, recycling material, powering factories with renewable energy and even cutting down on transportation emissions [8].
In this case study we aim to compare the use of a mobile device modeled on the fundamental design concept of a modular phone with standard mobile phone use. This comparison will be assessed across a 10-year period accounting for maintenance of key modular components. We quantify and assess the environmental sustainability with simple estimates of Carbon and Energy flows, using the Ansys Granta EduPack Eco Audit streamlined Life Cycle assessment tool, to have a comparison of environmental impact of the modular concept phone in comparison to a standard one.

2. Comparing Smartphones Fairly

In order to answer our question, or articulation, 'Is the modular design concept such as "Fairphone" more sustainable than other mobile devices', we can use the Embodied energy and Climate change

(CO2-equivalent) footprint as proxies for environmental performance and compare these for the equivalent use of standard mobile devices across a 10-year period. Using the Eco Audit tool, this can be assessed by specifying bill of materials (BOM) and evaluating both proxies across four key lifecycle stages; Material preparation, Manufacture, Use and End-of-life (EOL) as well as Transport.

Creating a full BOM for the Fairphone proxy is complicated because some of the data for material masses is not publicly available. Is it then possible to construct a representative BOM? To get around this we simplify our argument to instead address only the key components of the device. Since the Fairphone gains some of its sustainable characteristics from the modular design, allowing easy part replacement and refurbishment, we can reduce the BOM to standard components. Specifically, components that are likely be replaced during its lifetime and/or have significant contributions to the BOM, namely: the LCD panel and protective glass, Battery, Frame and cover and Printed Circuit Board (PCB).

How should mobile devices with different lifetimes be compared? Using this approach, the environmental sustainability of the scenario that a reference smartphone is used and replaced across a 10-year period, or a modular designed mobile, like Fairphone, is used with repairs instead of having to replace the entire mobile, can be assessed and compared. The average life of a smartphone, around 2.5 years, can be accounted for by letting every item in the BOM be multiplied by four, representing the use of 4 mobiles. There is no need to replace batteries, for example. In doing so, it is assumed that one constantly possesses a mobile phone across the entire 10-year lifetime. If four mobile devices are used, four times the materials and transport are needed. For the Fairphone, a reasonable number of replacement glasses, batteries and PCBs are included in the BOM, over 10 years. The BOM for both the reference smartphone and Fairphone proxy are displayed in Figure 2.

Reference Phone	Material	Recycled content* (%)	Part mass (kg)	Qty.
Screen LCD	LCD panel (liquid crystal display)	Virgin (0%)	0.06	4
PCB	Printed circuit board assembly	Virgin (0%)	0.003	4
Back Cover	PC (30% graphite fiber)	Virgin (0%)	0.016	4
Mid Frame	Aluminum, commercial purity, S150.1: LM0-M, cast	Virgin (0%)	0.034	4
Gorilla Glass	Alumino silicate - 1720	Virgin (0%)	0.003	4
Battery	Li-Ion, rechargeable battery (for laptops)	Virgin (0%)	0.064	4
Total				**24**

*Typical: Includes 'recycle fraction in current supply'

Fairphone Proxy	Material	Recycled content* (%)	Part mass (kg)	Qty.
Screen LCD	LCD panel (liquid crystal display)	Virgin (0%)	0.033	2
Screen LCD	LCD panel (liquid crystal display)	Virgin (0%)	0.027	2
PCB	Printed circuit board assembly	Virgin (0%)	0.003	1
Back Cover	PC (30% graphite fiber)	Virgin (0%)	0.016	2
Mid Frame	Aluminum, commercial purity, S150.1: LM0-M, cast	Virgin (0%)	0.034	2
Gorilla Glass	Alumino silicate - 1720	Virgin (0%)	0.003	4
Battery	Li-Ion, rechargeable battery (for laptops)	Virgin (0%)	0.064	4
Total				**17**

Figure 2. Bill of materials for a reference smart phone (left) and a Fairphone proxy (right). For many products, not just mobile phones, life cycle assessments (LCAs) have already been conducted and published. A key part of an LCA is the BOM defining that product. So, in a published LCA of the Fairphone, the component masses might be found. Here, we accept that the masses may not be exact. In this example, the masses of the components listed are found in [7] in using their BOM, and the methods outlined within.

To represent these components in Ansys Granta EduPack Software, there is an Electrical components section in the materials universe, within the Level 3 Sustainability database, that has a range of Eco Audit components. This includes ‘LCD panel’ for the liquid crystal display, ‘Printed Circuit Board’ for the PCB and a standard ‘Li-Ion, rechargeable battery’. There is, however, no frame, cover or protective glass, which must still be accounted for. In this study, the frame and cover are split into two components ‘Mid Frame’ and ‘Back Cover’. These are usually constructed from Polycarbonate and Aluminum (respectively); both can be found in the Ansys Granta EduPack Material Universe. Before specifying the masses, it is also necessary to research how the materials are disposed of. Albeit, most of these decisions would only affect the second life.

An example of the importance of this can be seen with the LCD panel. In a published LCA of a Fairphone [7], which is either reused or recycled. To account for this, we can simply split the mass by the proportions that are reused and recycled and list it on the BOM as two LCD components, one which is 100% recycled and the other that is 100% reused where the combined mass of both components is equal to the total mass of the LCD. Since these are Ansys Granta EduPack components, the processes are included in the material values already. For the reference smartphone, the LCD is neither recycled, nor reused, so we put Landfill in this box. As mentioned above, this will only be seen in the EOL potential, for next life.

Now, the LCD panel component accounts for the display, but not the durable Gorilla glass that is placed over the LCD to keep it protected. A quick Internet search informs us that Gorilla glass is composed of Aluminum Silicate. In this study we used Aluminum silicate 1720. The printed circuit board (PCB) mass was found by looking for similar component masses. In this case, the Sony Z4 mobile PCB mass was used. The Gorilla glass mass can be estimated by taking the volume of the smartphone screen (also in the LCA) and using the density of Aluminum silicate, found in the material record of Ansys Granta EduPack software. By using these values, the mass of 3 g was derived. The rest of the EOL data was found in the reference study of a Fairphone LCA [7]. Here, we use 0% Removed and 100% Recovered except for PCB which was specified 10% recovered. A detailed breakdown of the bill of materials from Eco Audit for the Fairphone proxy can be found in Figure 3.

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	End of life
2	Screen LCD	LCD panel (liquid crystal display)	Virgin (0%)	0.033		None
2	Screen LCD	LCD panel (liquid crystal display)	Virgin (0%)	0.027		None
1	PCB	Printed circuit board assembly	Virgin (0%)	0.003		Landfill
2	Back Cover	PC (30% graphite fiber)	Virgin (0%)	0.016	Polymer molding	Re-manufacture
2	Mid Frame	Aluminum, commercial purity, S150.1: LM0-M, cast	Virgin (0%)	0.034	Casting	Recycle
4	Gorilla Glass	Alumino silicate - 1720	Virgin (0%)	0.003	Glass molding	Landfill
4	Battery	Li-Ion, rechargeable battery (for laptops)	Virgin (0%)	0.0642		Downcycle

Figure 3. Bill of materials as seen in Eco Audit for the Fairphone concept. Complete BOM for a Fairphone type model, accounting for various module replacements such as the battery, glass, frame and LCD in accordance with hypothetical use across a 10-year period. The BOM was created using the Ansys Granta EduPack Eco Audit tool

Moreover, the Eco-Audit Processing method, End of Life, Transport and Use need to be filled out before any results can be obtained. For all materials from Ansys Granta EduPack software, standard processes can be selected in the Eco Audit BOM. Conversely, for the electrical Eco Audit components, the process energy is included in the material phase.

3. Transport and Use

When considering the lifetime of a Fairphone model compared to a standard mobile, as previously stated, the use of raw materials in replacement modules/mobiles is accounted for. However, it is also vital that the transport of processed materials and the assembled mobiles is included. Using the transport section of Eco Audit this was evaluated and is displayed in Figure 4. In this instance the consumer was modeled to be based in the UK approximately 80 km away from Dover port. Again, using our Eco Audit, it is detailed that land transport is conducted by truck, short international journey by ship and intercontinental journey by air freight. However, manufacturing and import locations remain to be selected. Fairphone is a transparent business operation, owing to their strong ethical standing. This allows us to find and use the actual location of their suppliers, manufacturers, and distribution centers. In this instance a random supplier in Africa and a Fairphone manufacturing plant in Suzhou were selected [9]. It was then assumed that from China, the mobile device would be transported by airfreight to Fairphone's distribution center in Amsterdam and from there by container ship to Dover. The final transport is by truck to a shop where it is then purchased by our consumer. All distances were calculated using an Atlas and input into the Eco Audit.

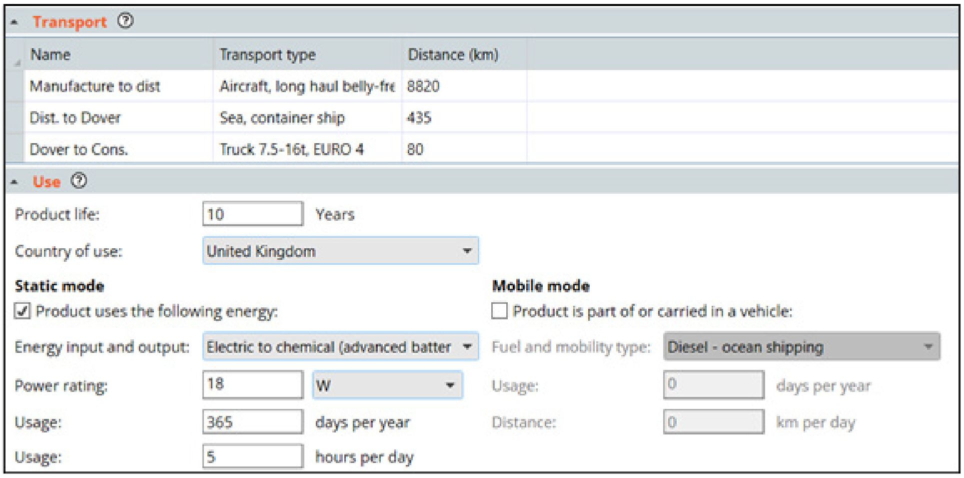

Figure 4. Input data for the Eco Audit of both the Fairphone proxy concept and the reference smartphone for Use case and Transportation of components.

If the country of use is the United Kingdom, we can set the location accordingly. In this case it was assumed that power was supplied by the electric to chemical process (power to mobile battery) and that it was via a standard 18W charger, as an example.

Moreover, an arbitrary use period of 5 hours a day for 365 days (5 hours every day) was selected. Since the energy use from 10 years of use turns out to dominate the profile, it is interesting to add a country of use with a less typical European energy mix. We have decided to include Norway, which has hydro power as the near-total contribution to its electricity mix, meaning very small energy losses and low emissions. The results are shown in the next section.

4. Comparing environmental performance

We are now in a position to start comparing resources and emissions from the two main alternatives. The Fairphone proxy model does perform better than the reference, according to these results, both in the energy and Climate change (CO2-eq), presented respectively in Figures 5 and 6, across the key phases of the product life cycle. The material contribution to the lifecycle energy is relatively small compared to the regular charging during use. The Fairphone proxy model uses a few percent less energy than its rivals in the UK, because in aggregate less of the phone is replaced when compared to the smartphone model where the entire phone is replaced after 2.5 years.

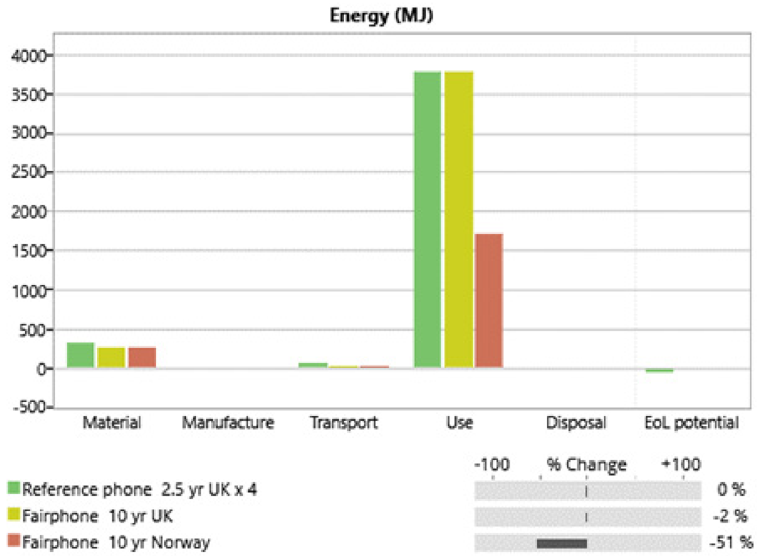

Figure 5. Results of Eco Audit for embodied energy throughout modeled life cycle of Fairphone concept and reference smartphone across a 10-year period.

The total energy use is, however dominated by the daily regular charging. In March 2024, roughly 37% of the electrical energy generation in the UK was achieved using fossil fuels [10]. Conversely, Norway produces 97% of it's electricity with hydropower, waste and wind.

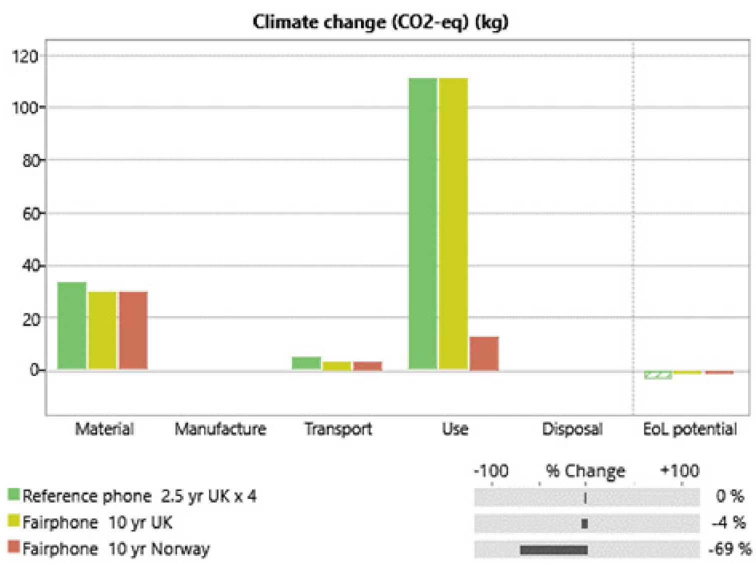

Figure 6. Results of Eco Audit for Climate change (CO2-eq)(kg) throughout modeled life cycle of Fairphone concept and reference smartphone across a 10-year period.

It may be surprising to find that a Fairphone proxy model charged in Norway consumes only around half of the energy compared to the UK. This is due to the very high efficiency of hydropower, compared to most other conventional electricity generation methods (natural gas, nuclear power etc), because of high heat losses that counts towards the total use. The remarkable difference is even more pronounced when CO2-equivalent emissions are considered over the lifecycle. A 69% reduction compared to UK (or other similar European countries).

When looking at manufacture, material and transport we see that not only are the differences very small, but they are practically negligible compared to the Use phase and, in fact, we see a similar trend across the CO2-equivalent emissions. It should be noted that there is a very small difference in both material use and transport in the Climate change chart. The reference phone (standard mobile model) device emits slightly more CO2 only because more raw material is required for standard device use across the 10-year period. This small difference is, of course, amplified by the billions of smartphones that are currently in use so it would be relevant. It also highlights the importance of the energy mix used.

5. Conclusions

So, what can we learn from our results? Obviously, the Use period, where the majority of emissions appear. This means how and where you charge and use your device is important (similar to an electric car). Moreover, whilst there are differences in Energy and Climate Change (CO2-eq) when comparing the use of a standard reference mobile and a modular concept, such as Fairphone, these arise from the quantity of components in the BOM. The standard mobile use case was modeled on 4 new devices required during a 10-year period. If the "Fairphone" needed more frequent repairs than accounted for in the BOM, the two proxies – the Energy and Climate change (CO2-eq) emissions could be underestimated.

6. Expansion: sustainability assessments with the five step method discussion

In this case study we have asked the question, Is the modular design concept such as "Fairphone" more sustainable than other mobile devices? Now, there is a systematic way to assess sustainability proposals. It is described in the textbook by Professor Mike Ashby - Materials and Sustainable Development [11] (Figure 7). It is based on 5 steps that clearly define the articulation, in our case as defined above. A timescale needs to be selected our case 10 years. It needs to have a size – we are talking about potentially a billion phones, or, more modestly the life-span of 4 regular smartphones.

In step 2, Stakeholders are named, followed by a stakeholder analysis. The information collated at the second step will inform the 3 step - fact finding. The question is then scrutinized with a concept of three "capitals" human/social, natural and manufactured in step 4.

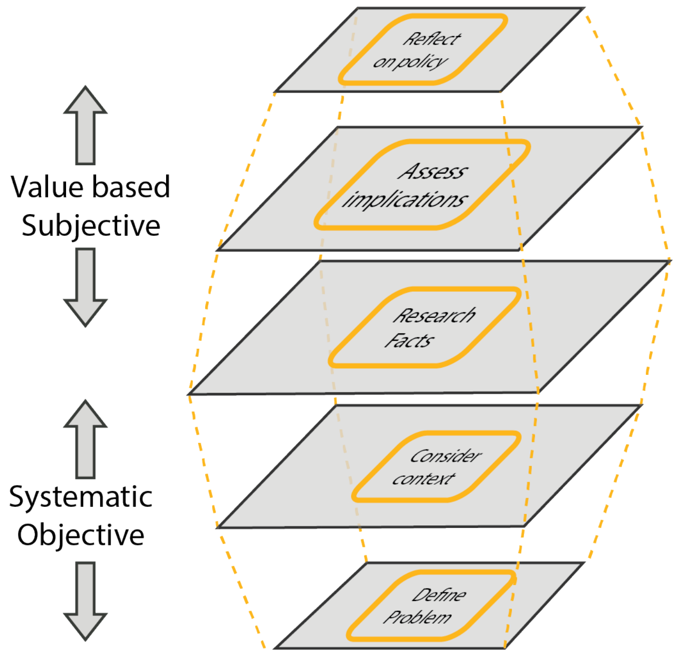

Figure 7. Layering as a way of thinking about complex problems (Fig. 13.1 in [11])

The fifth and final step in this methodology (Figure 8) is the reflection on alternatives. All these steps are well suited to an educational context and adaptable to fit different groups and settings. It has also been used to aid decision-making to address complex sustainability challenges. More details and guidance can be found in the Ansys Sustainability toolkit [12] and Ashby's textbooks [11] and [13].

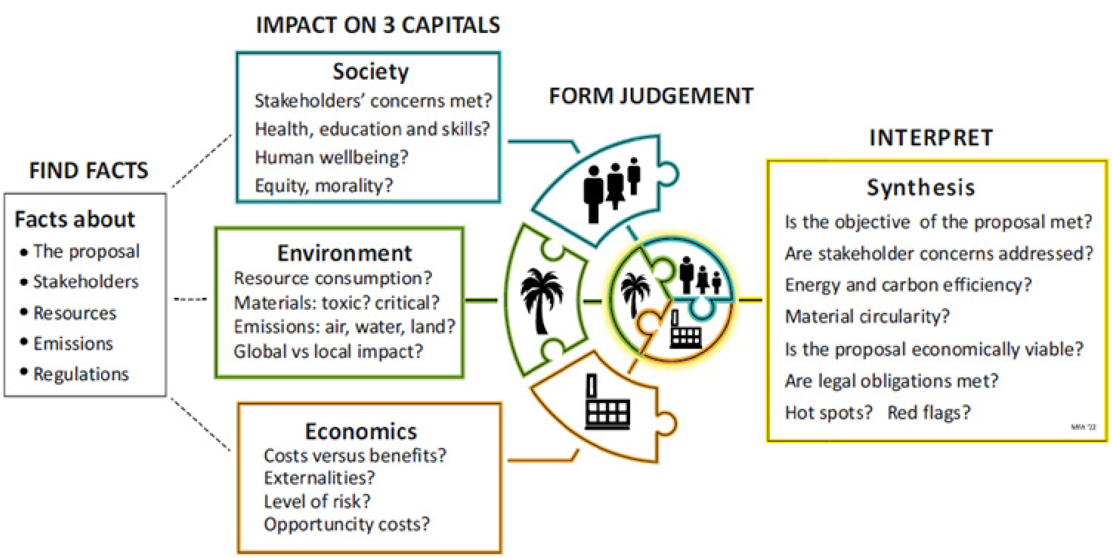

Figure 8. Overview of the 5-step method by M.F. Ashby [9]

The way to use the methodology in an educational / workshop setting is suggested below in Figure 9.

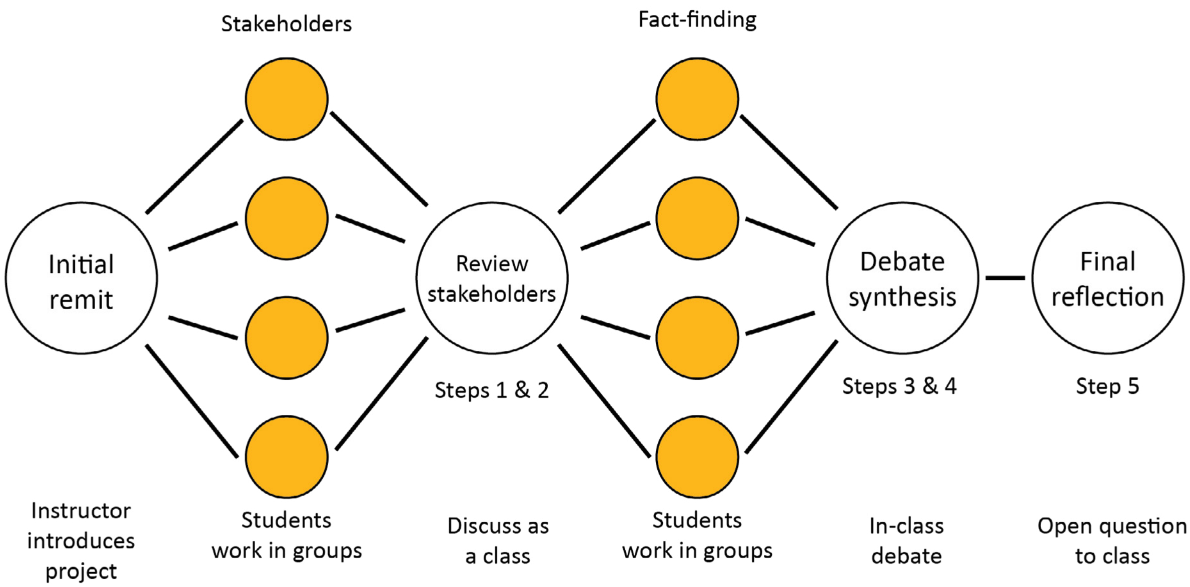

Figure 9. Schematic overview of workflow in class [13]

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